IMP. BUR.
25 JAN 1930
ENTOM.

TECHNICAL BULLETIN No. 135 NOVEMBER, 1929

THE CORN BORER IN CENTRAL EUROPE

A REVIEW OF INVESTIGATIONS FROM 1924 TO 1927

BY

K. W. BABCOCK
Associate Entomologist

AND

A. M. VANCE
Assistant Entomologist
Division of Cereal and Forage Insects
Bureau of Entomology

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

TECHNICAL BULLETIN No. 135 NOVEMBER, 1929

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE CORN BORER IN CENTRAL EUROPE

A REVIEW OF INVESTIGATIONS FROM 1924 TO 1927[1]

By K. W. BABCOCK, *Associate Entomologist*, and A. M. VANCE, *Assistant Entomologist, Division of Cereal and Forage Insects, Bureau of Entomology*

CONTENTS

	Page
Introduction	1
Distribution surveys	2
Austria	3
Germany	3
Poland	4
Rumania	4
Czechoslovakia	5
Yugoslavia	5
Greece	6
The central European plains	7
Climate of the central European plains	7
Agriculture in Hungary	8
The distribution and cultivation of corn	10
Varieties of corn and methods of planting	12
The corn borer as a native of the central European plains	14
Original host plants	14
Seasonal history	15
Number of generations per year	17
Extent and economic results of infestation	18
Natural enemies	32
Parasites	32
Disease	35
Other natural enemies	35
Control	36
Agricultural practice	37
Environmental factors in control	43
Conclusions	53
Literature cited	54

INTRODUCTION

The investigations of *Pyrausta nubilalis* Hbn. which have been carried on in central Europe by the United States Department of Agriculture, and which have now covered a 4-year period (from 1924 to 1927, inclusive), were founded upon two demands for information. The first arose from the realization that certain specific problems concerning the seasonal history and habits of this insect could not be solved and the proper conclusions drawn by the use of data obtained solely from research experiments in the new home of the insect, where

[1] The writers take this opportunity to thank the various European entomologists, agriculturists, and officials of the ministries of agriculture who have personally assisted in making these investigations possible. The interest and active cooperation of Drs. Karl Escherich and Hermann Eidmann, Dr. Alexander Oglobiin, Dr. Joseph Jablonowski, Dr. W. Knechtel, and Dr. Constantin Isaakides in assisting the writers in their investigations in Germany, Czechoslovakia, Hungary, Rumania, and Greece, respectively, are deeply appreciated. For the excellent information obtained from the province of Baden, in Germany, and willing cooperation with the senior writer, the writers are indebted to Dr. W. Zwölfer, in charge of corn-borer investigations at the plant-breeding experiment station of the Baden Agricultural Chamber, located at Rastatt, Baden. The detailed data supporting statements contained in the sections of this bulletin dealing with the increase of infestation and a corresponding increase in the quantity of a favored host plant grown, as well as the statements regarding the effectiveness of clean-up as a means of control of the corn borer, have been made available to the senior writer through personal correspondence. The

54736°—29——1

gradual adaptation to a new environment was taking place. The second demand for authentic data from the native home of the insect arose from the immediate necessity for facts which might aid in the adoption of suitable quarantine, scouting, and control policies.

The needs for this information have been stated, and the fundamental problems in the study of the ecology of the insect have been presented, in two publications by the senior writer (*1*, *2*).[2] The habits and life history of the insect have been discussed thoroughly in two bulletins issued by the United States Department of Agriculture (*3*, *6*). In a more recent bulletin Thompson and Parker (*5*), of the field laboratory at Hyères, France, devoted to the study of the corn borer, have, in a general treatment of the insect in Europe, presented its relationship to various environments.

The writers had intended to present in detail the mass of information which has been collected during the four years 1924, 1925, 1926, and 1927, but it seems better to present at the outset a brief general summary of the entire project, reserving for later and more detailed discussion the several phases of the investigation.

The more detailed studies discussed in this publication were made principally in Hungary and northeastern Yugoslavia, in the region embraced by or contiguous to the confluence of the Theiss and Danube Rivers. Cursory studies were also conducted in Austria, Germany, Poland, Rumania, Greece, and Bohemia and Slovakia in Czechoslovakia.

DISTRIBUTION SURVEYS

Since the project here discussed includes the work of defining the limits of distribution of *Pyrausta nubilalis*, a certain portion of each of the years 1924 to 1927, inclusive, was devoted to the collection of biological data bearing upon this point, from Austria, Germany, Poland, Czechoslovakia, Rumania, southern and western Yugoslavia, and Greece. The results of the work done in each of these countries will be briefly considered. For the convenience of the reader a map (fig. 1) has been prepared, presenting features of the more important portion of the corn belt in central Europe and the number of larvae per 100 plants of corn, averaged for the four years 1924–1927. The figures representing this infestation are shown under the names of towns. The figures for Cegléd, Hatvan, Miskolc, Nyíregyháza, and Kalocsa are for 1927 only, but are believed to represent average conditions in these localities. The shaded portion represents the center of the corn belt and the center of infestation by the corn borer.

---

senior writer takes this opportunity to express his gratitude to Doctor Zwölfer for his innumerable kindnesses.

In all countries in which the writers have carried on field observations, had it not been for the assistance of the Foreign Service of the United States Department of State the efficiency of the organization would have been materially decreased. The writers again thank the members of the consulates and legations in the countries visited for their interest and assistance in the official problems. Particular credit is due to the consular and legation staffs at Budapest, Hungary, for their cooperation with the active work of this project, the headquarters of which were located in that city.

Since 1920 the senior writer has been in charge of the ecological work on the corn borer conducted in the United States and Europe by the Bureau of Entomology, and personally directed this work in Europe in the years 1924 to 1927, inclusive. The junior writer was detailed in the spring of 1926 to assist in this work in Europe, and through two consecutive seasons was, under the direction of the senior writer, personally in charge of the collection there of all field data concerning this project. Among the topics that have been specially his are the data upon larval survival, infestation of sorghums, and selection of fields as to soil type.

The writers are indebted to W. R. Walton, J. E. Graf, J. A. Hyslop, and S. B. Fracker, who reviewed the manuscript and made valuable suggestions as to the form of presentation of the data and conclusions.

[2] Italic numbers in parentheses refer to "Literature cited," p. 54.

Thirty per cent of the arable land of this area is devoted to the production of corn. The region between this area and the heavy line to the north, west, and south of it is next in importance, 20 per cent of its arable land producing corn.

AUSTRIA

In 1924 extensive field observations were made in the district about Salzburg and Linz, but no evidence of the corn borer was found there. In the vicinity of Graz, in Styria, an infestation of 8.9 per cent was found in the plants. North from this city, up the valley to the junction of the rivers Mürz and Mur at Bruck, the infestation gradually

FIGURE 1.—Map of the more important portion of the corn belt in central Europe. The numbers under the names of towns indicate the average local infestation by the corn borer, in larvae per 100 plants of corn. The shaded area represents both the center of the corn belt and the center of infestation by the corn borer

decreased to an average of 2.7 per cent. No infestation was found at Kapfenberg, near by, where practically no corn is grown. (Pl. 1, A.)

GERMANY

Through the cooperation of Doctors Escherich and Eidmann, of the University of Munich, and Doctor Zwölfer, of the plant-breeding experiment station of the agricultural chamber, Rastatt, Baden, several regions in Bavaria and Baden were thoroughly scouted. The conditions found in Bavaria differ markedly from those witnessed in the corn areas of Baden, the warmest section of Germany.

In Bavaria the regions about Übersee, in southern Bavaria, and Würzburg and Bamberg, in northern Bavaria, were scouted and a

slight infestation was found in every town where corn was grown. (Pl. 2.)

Owing to the fact that during the season of 1925 the corn borer did an appreciable amount of damage to grain corn grown on the fields of the Baden experiment station at Rastatt (pl. 3, A, B), a thorough investigation of the life history, habits, and control of the insect was instituted under the supervision of Doctor Zwölfer in the spring of 1926.

The country surrounding the city of Baden is a flat plain, agriculturally rich, lying at the foot of the Black Forest. The chief production of grain corn there began in 1920 and increased rapidly up to 1922, when the corn borer was first noticed as a possible pest. The infestation in this region has steadily increased up to the season of 1927 and it is feared that if this increase continues the growing of grain corn will be seriously handicapped. A survey of this area, made by the writers in company with Doctor Zwölfer in 1926, showed average infestations of 60.3 per cent of the plants and 23.1 per cent of the ears, and the presence of 122 borers per 100 plants.

A fact of particular interest in the conditions at Baden is that with a very low larval population severe commercial damage can be inflicted upon the native Bädischer Landmais, the local type of corn. The plants are small, attaining when mature a height of from 4 to 5 feet, and have slender stalks; the problem of control is thus more acute in this area than in regions where a much more severe infestation is necessary to produce damage.

In 1927 Doctor Zwölfer (7) published an excellent account of the work done in Baden and with it a summary of the status of the borer in Germany as a whole. This paper should be consulted for details on the status of the insect in Germany.

POLAND

From officials and from reports of field workers, it has been learned that there is no record of serious injury from the corn borer in Poland, but that at the present time the insect is generally distributed in small numbers throughout the corn-producing section in the southeastern part of the country. This region, comprising practically all of the corn-growing land in Poland, lies along the banks of the main branch of the Dniester River, extending north to the city of Lwów (Lemberg). The center of corn culture is at Tarnopol, where annually 35.8 per cent of the land is devoted exclusively to this crop. The percentage of land used for producing corn decreases from 32.3 at Stanislau to 5.1 at Lwów (Lemberg).

RUMANIA

With the cooperation of Doctor Knechtel, professor of applied zoology in the University of Bucharest, the writers have collected information from two distinct corn-growing regions of Rumania. The first comprises the Wallachian Steppes, represented by the localities about Domniţa and Gherghiţa, and the second lies in Transylvania, Cluj (Klausenburg) being the center of observation.

A large quantity of corn is grown in each area, the plantings being more extensive in the first than in the second. An examination

A.—Valley in the Semmering Range, near Kapfenberg, Austria.
B.—Valley of the Vardar River, above Skoplje (Üskŭb), southern Yugoslavia.
C.—Corn in the valley of the Vardar River.

A.—Agriculture near Bamberg, Germany.
B.—Fodder corn, July 17, 1926.
C.—Flint corn, July 17, 1926.

A and B.—Corn growing in fields of experiment station, near Rastatt, Baden, Germany.
C.—View near Larissa and Trikkala, Thessaly, Greece.

showed that 3.2 per cent of the plants were infested in the Wallachian region, while in Transylvania the infestation averaged 76.4 per cent of the plants and 26.2 per cent of the ears, and the larval population averaged 588 borers per 100 plants.

In contrast with the level stretches of the Wallachian Steppes, the Transylvanian region, of which Cluj (Klausenburg) can be taken as representative, is hilly, with a slightly moister climate. Drought is a normal feature of the climate in the former region, as 1924 and 1925 destroying the corn before maturity, whereas in Transylvania such severe dryness occurs less frequently. This climatic divergence may be the real explanation of the difference in infestation between the two regions.

CZECHOSLOVAKIA

Since the southern portion of Czechoslovakia is topographically speaking, a continuation of the Great and Little Alföld (plains) of Hungary, the collection of data throughout this region has been more systematic and detailed than it would have been if the object were purely one of determining the distribution of the insect.

The corn region in Czechoslovakia, represented by the towns of Bratislava, Komárno, and Brno (Brünn), is contiguous with the Little Alföld of northwestern Hungary, and the district in which lie the towns of Košice (Kaschau), Užhorod, Mukačevo, and Beregsas represents the northern continuation of the corn areas of northeastern Hungary.

Both of these areas merge into regions which constitute the northern limits of corn growing in central Europe. The most northerly point where corn can be successfully grown, at Chlav, in Bohemia, was visited in 1925, and examinations were made in the experimental plats at the agricultural station there. Although these plantings had been carried on during the preceding five years, no evidence of the presence of the insect had been noted.

The infestation in northwestern Czechoslovakia is discussed on page 38. For details of the intensity of infestation in this country, see Table 6.

YUGOSLAVIA

SOUTHERN YUGOSLAVIA

In the season of 1925 the district surrounding the town of Shuplje (Üskub) was visited. (Pl. 1, B, C.) This town lies in the valley of the Vardar, a small river which nearly dries up in the summer. The valley is about 2 miles wide at this point and is surrounded by high mountains entirely devoid of trees. The vegetation of the valley is of the semiarid type, and agriculture there is chiefly found along the banks of the river, where all plantings are irrigated. The chief crops are small grains, corn, sugar beets, Macedonian tobacco, hemp, and the opium poppy. Of these, tobacco and the poppy are the most important. The farm practice is extremely primitive and conducted on a small scale. During five months of the year the climate is characterized by intensely hot weather, and severe droughts are of frequent occurrence.

The infestation by the corn borer in this region is very light. During the course of the scouting trip only 28 larvae were found.

among which were one prepupa and one newly formed pupa, as evidence of summer pupation. The actual line of demarcation between the one-generation and two-generation areas could not be determined definitely, owing to the lack of material. Probably, however, it lies in the region of the divide between the valleys of the Vardar and Morava Rivers.

WESTERN YUGOSLAVIA

Through the courtesy of the Royal Yugoslav Minister of Agriculture, permission was given an assistant, M. S. Popovitch, to make a scouting trip through the corn-growing areas of the Dalmatian coast. Extracts from the report of the latter describe the territory covered and the observations omitted as follows:

Most of my observations were made in the five large districts of southern Dalmatia: Perovero, Metkovo-Pelje, Ostrovo-Pelje, Konavli, and Župa. In all these districts I found the second [generation] followed by their brood. As to degree of infestation, that in Peljesac, Metkovo-Pelje, and Ostrovo-Pelje was 10 per cent; in Konavli, 5 per cent; and in Župa, 3 per cent.

Elsewhere in Yugoslavia, in the localities of Sarajevo, Ulice, Čačak, Kraljevo, Kruševac, and Skoplje, also visited by Mr. Popovitch, either the presence of the insect was not discovered or the infestations were light.

Mr. Popovitch, in another report, discusses the types of corn grown in the areas visited:

Throughout southern Dalmatia, Montenegro, Bosnia, and Croatia [but] one is cultivated to the largest extent. In Montenegro and in Dalmatia the [second] first is Cinquantino. [One] sort, known as "Kastrum," was introduced into Dalmatia between 1905 and 1910.

GREECE

Through arrangements made possible by Constantin Issakides, director of the Phytopathological Institute at Athens, the junior writer in the summer of 1926 made a scouting trip to some of the important corn-growing regions of Greece, selecting as typical Aliartos (near Lake Copias), where 8,000 acres of corn are under cultivation by subirrigation, Trikkala (pl. 3, C) (center of Thessaly), Karditsa (20 miles from Trikkala), and Saloniki (Macedonia).

The information obtained at each point can be briefly summarized. At Aliatros the infestation was very light. On July 24 it was found that 30 per cent of the larvae had pupated, and from a larva collected July 26 an adult emerged on July 29. The insect has never been abundant in this locality. At Trikkala scattered specimens were found on July 25, and pupation was beginning. At Karditsa no trace of the corn borer was found. Scattered specimens of the borer were found at Saloniki.

The insect seems to be distributed generally over the chief corn-growing sections of Thessaly and Macedonia, but in such limited numbers that it can not be considered an economic factor in the growing of corn. In 1925 pupation of the first-generation larvae occurred in the latter part of July and emergence in the first week of August.

THE CENTRAL EUROPEAN PLAINS

Owing to the concentration of corn in the central European plains and the similarity of this region in climate to that of the Corn Belt of the United States (although less extreme as to the heat of summer and the cold of winter), the chief attention of the investigators was turned to these plains, drained by the Danube River and its chief tributaries, the Tisza, Maros, Drava, and Sava Rivers. This depression, forming a part of the countries of the present Czechoslovakia, Hungary, Rumania, Yugoslavia, and Austria, ranges from 50 to 1,300 feet in altitude, for the most part averaging from 200 to 500 feet. It forms, as viewed on a contour map, an immense elliptical area, bounded on the west by the Italian and Austrian Alps, on the north by the Carpathian mountains, on the east by the Transylvanian Alps, and on the south by the most northerly ranges of the Dinaric Alps.

To discuss a region so diversified would require a paper devoted principally to that one feature. Since this bulletin is restricted to the presentation of data concerning the status of the corn borer in central Europe, only a brief description of the types of agriculture in important centers and the chief varieties of corn grown are presented.

As Hungary ranks conspicuously both as a corn-producing country and as a center of infestation by the corn borer, special attention will be given to its agricultural practices.

CLIMATE OF THE CENTRAL EUROPEAN PLAINS

The region which has been described is characterized by a climate which might be termed a transition from that of the coast of western Europe to the true continental climate found in Russia. It is not possible, however, to define sharply the type of this climate, since the normal precipitation has features quite commonly encountered in a study of the type of climate characterizing the region about the Mediterranean Sea. Precipitation occurs chiefly with pressure minima originating over the Adriatic Sea, and moving across this region in a northeasterly direction.

The seasonal characteristics of the temperature and precipitation may be seen by referring to Tables 1 and 2, in which are given by intervals of from one to three months, normals for the area. The total normal mean temperature and the total normal mean precipitation for the hibernation period are the two respective totals for the interval covered by the months of October, November, December, January, February, and March. This period, and the other periods, covering from one to three months, designated in the box heads, were chosen for the sake of separating the year into portions suitable for the study of the corn borer in its relation to temperature and precipitation. The maximum precipitation generally occurs in May and June. The outstanding climatic feature preceding the appearance of these early summer rains is a sharp rise in temperature in March and April. The rains cease abruptly, with only occasional showers during August and September, increase again at the beginning of winter, and decrease to a minimum in January, February, and March. The corn belt experiences a cold, dry winter, with sufficient snowfall to protect winter grains.

TABLE 1.—*Normal temperature, for the portions of the year named, at specified towns of Hungary*

Town	January to March	April and May	June to August	September to December	Total for the year (annual mean)	Total growing season (April to September, inclusive)
	°F.	°F.	°F.	°F.	°F.	°F.
[illegible]	32.1	53.1	69.1	48.2	50	[illegible]
[illegible]	32.1	52.3	69.1	51.1	51.1	[illegible]
[illegible]	32.1	52.3	69.1	51.1	51.1	[illegible]
[illegible]	32.4	53.4	69.4	51.4	51.4	[illegible]
[illegible]	33.1	53.1	69.1	51.1	51.1	[illegible]
[illegible]	32.1	53.4	71.1	53.1	52.4	[illegible]
Average	32.2	53.1	69.7	51.1	51.4	[illegible]

TABLE 2.—*Normal precipitation, for the portions of the year named, at specified towns of Hungary*

Town	January to March	April and May	June to August	September to December	Total for the year (annual mean)	Total growing season (April to September, inclusive)
	Inches	Inches	Inches	Inches	Inches	Inches
[illegible]	1.26	1.26	2.28	2.28	7.08	4.41
[illegible]	1.18	1.26	2.28	2.17	7.17	4.41
[illegible]	1.26	1.26	2.28	1.96	6.76	4.41
[illegible]	1.49	1.57	2.16	2.28	7.48	4.41
[illegible]	1.26	1.26	2.28	1.77	6.77	4.41
Average	1.29	1.37	2.26	2.09	7.04	4.41

The warmest month of the year is generally July, although the three summer months differ but little in temperature. The coldest month is generally February, and October and April have practically the same mean temperature.

Throughout the central portion of the corn belt there are strong winds, the direction of the prevailing wind of the year being northwesterly. Northwesterly and westerly winds occur in the summer, but during the winter the prevailing wind is from the southeast. In the latter part of summer it is not unusual for the winds to blow a gale for three or four days at a time, and in years of bad infestation by the corn borer the breaking of the plants of corn by the winds has a distinct influence upon the resulting damage to the crop.

A characteristic of this area is sudden thunderstorms, accompanied by high winds and sometimes by hail, which are frequent during June and often cause severe damage to the crops.

AGRICULTURE IN HUNGARY

The impression gained of Hungary as a whole is that the agricultural practice there is clean and careful, although hand labor prevails on the majority of farms. Throughout the northwestern part of the country much of the land is planted in strips about 20 yards wide and 100

yards long, with a diversification of crops suited to the requirements of the owner. This type of culture has become more common since the war, after the close of which many of the large estates were divided into small holdings, ranging in size from 15 to 500 acres. On the large estates yet existing the land is divided into fields larger than these holdings, the size depending on the terrain and the system of crop rotation practiced by the owner. On such estates the "owner's fields" are the best cared for and usually suffer less infestation than the "owner's peasants fields," from which the peasant receives a portion of the crop as part payment for his labor during the season. The third type of cultivated ground, ordinarily designated as the "peasant's field," usually has a poor stand, is badly cultivated and weedy, and gives an inferior yield.

The use of crop rotations, the preparation of the soil, and the cultivation of the crop vary widely, and all gradations exist from very good agricultural practice to very bad. The impression is gained, however, that the cultivation of corn is kept at as high a standard as it is in the United States. On the larger estates, as might be expected, the highest type of agricultural practice is found, the growers not only carrying on experiments in plant selection but also following carefully a system of crop rotation suitable to their needs.

A few facts will illustrate Hungary's importance as a grain-producing country. The seven principal agricultural products grown there in 1926 were, in the order of their importance, wheat, corn, rye, barley, oats, potatoes, and sugar beets. An average of 65 per cent of the yield of all of these, except the sugar beets, is obtained from farms of 145 acres or less, while the remaining 35 per cent is derived from the larger properties. This is not true, however, in the case of the production of sugar beets, 89.1 per cent of the yield of these is obtained from the large estates and the farms naturally convenient to the sugar factories and alcohol-distilling plants.

The importance of Hungary as a typical grain center is shown by some statistics of its crop yields in 1926. Its production of wheat was 71,488,563 bushels, or an average of 19.9 bushels per acre; of corn, 73,417,259 bushels, an average of 27.4 bushels per acre; of rye, 28,299,333 bushels, an average of 16.3 bushels per acre; of barley, 18,085,591 bushels, an average of 34.1 bushels per acre; and of oats 23,880,395 bushels, an average of 34.1 bushels per acre. Besides these grains, the yield of potatoes was 6,718,950 bushels or an average of 106 bushels per acre, and 1,680,152 tons of sugar beets were produced, or an average of 10.1 tons per acre.

Besides these important staples, garden beets, red onions, beans, cabbage, and other common vegetables are grown around such centers as Budapest, Szeged, and Debreczen. Other important crops grown are paprika, in the environs of Szeged; buckwheat, chiefly around Szombathely; hops, millet, hemp, broomcorn, flax, and tobacco, in the west-central region; pasture grass and vineyards, chiefly in the hilly and rolling sandy country. Fruits are also cultivated to a considerable extent, and much of the apricot and peach crop is used in the making of a native liqueur. The other principal crops are plums, pears, walnuts, almonds, and apples.

THE DISTRIBUTION AND CULTIVATION OF CORN

EASTERN HUNGARY AND EASTERN YUGOSLAVIA

The region of particular interest to this investigation, and the one which might be termed the center of the corn belt, lies between the Danube and the Theiss Rivers, extending from the towns of Baja and Szeged, in Hungary, and Subotica, in Yugoslavia, southward to the junction of these rivers and to the Drave and Save Rivers. In this region, known as the Bacska in Hungary and the Vojvodina in Yugoslavia, in which the corn borer is chiefly concentrated, the land is generally flat and extremely fertile. Although corn and wheat are the principal crops, the rotation usually includes sugar beets, spring grain, rye, mohar (a species of Setaria), barley, oats, hemp, and hops. Occasionally plantings of alfalfa are included in the rotation.

Throughout this large region there is to be found only a slight variation in the agriculture, although the practice may vary considerably, depending upon the size of the farm and the initiative of the owner. Before the World War there was a region of large estates and a highly developed system of tenantry. More recently these large holdings have been divided, and there is now a restriction as to the maximum number of acres one person may control.

This area is particularly suited to the cultivation of large fields and is comparable with the best lands in the center of the Corn Belt of the United States. Throughout the region cornstalks are commonly left in the fields during the winter, and in some cases they are not properly disposed of the following spring. Where the stalks are removed from the field they are hauled to a convenient spot near the farm buildings and piled into huge stacks. These stacks often contain stalks which are several years old. In many localities only a 3-year system of crop rotation is practiced, consisting of corn, wheat, and a fodder of the millet type (usually *Panicum miliaceum*).

In the northeast-central portion of the area, surrounded by a large expanse of drifting sand, is the locality about Debrecen (fig. 4, B) which, although it differs in many respects from the other centers of corn production, is included in this general region because the intensity of infestation in it differentiates it from the other areas discussed. The soil here is in general of looser texture than is found farther south. The region is also more heavily wooded, particularly the portion surrounding the town, where several tracts of oak forest have been preserved.

Corn is chiefly grown in small plantings, and a 4-year rotation locally called "Norfolk 4," consisting of alfalfa, wheat or rye, corn, and either sugar beets or spring fodder, seems to be generally practiced. As a common feature of agricultural practice one-third of the land is manured every five years with a mixture of horse and sheep manure, one-third treated with sewer water, and one-third superphosphated.

Corn is grown in quantity throughout the valleys in Transylvania. Another important area, although ecologically quite separated from the central European plains, as previously defined, is the extensive depression known as the Wallachian Steppe, drained by the Danube in Rumania and extending to the deltas at the Black Sea. This corn-growing area is separated from the former locality by the southern

Carpathians, or Transylvanian Alps, and the status of the corn borer in this region is very different.

WESTERN HUNGARY

Another important grain-producing area in the central European plains lies in western Hungary, mainly in the triangle formed by the Danube and Drava Rivers and a line drawn from Budapest to the Drava River through Székesfehérvár, Lake Balaton, and Nagykanizsa. This area, although including much level ground, is more rolling than the one just discussed. Three localities in this area, characterized by important differences, will be mentioned.

Szombathely is the first, and is in the extreme west-central part of Hungary, near the Austrian border. Nearly all corn grown there is in small garden patches maintained almost solely for the immediate needs of the families. The soil is light, gravelly, somewhat sandy, and less adapted to large areas of corn planting than any other part of the area. This is one of the chief buckwheat-growing localities in Hungary, and produces considerable tobacco.

There is considerable corn production about Nagykanizsa, in the southwestern corner of Hungary, south of Lake Balaton (pl. 4, C). The land there is rolling and sparsely wooded. Corn is grown in valleys between wooded hills. The soil is fertile, although sandy in isolated spots. A few miles farther southwest, near the town of Muraberesztúr, on the flatter land of the river valley of the Drave, is found another center of corn production. Large quantities of the adapted Cinquantino flint are grown here.

Pécs, near the southern boundary of Hungary, about midway between the Drave and Danube Rivers, lies in a semimountainous country, well wooded, and with rich land in the valleys. A large quantity of corn is produced in the rolling country and on the plateau surrounding Tésenv, a few miles north of Pécs. The soil is usually of the clay-loam type and, in general, the agricultural practice is good. The ears of corn are stripped from the stalks in the field, and the stalks left standing until the cattle have fed upon the leaves; the stalks are then cut and carried to the barnyard, where they are used throughout the winter for bedding, fuel, feed, other farm purposes. Around Tésenv the remnants are generally burned in the spring. Using a portion of the stalks in the compost pile is also a local practice.

NORTHWESTERN HUNGARY

The last important area of corn production to be mentioned, included in the central European plains, is that known as the "Little Alföld," lying in the northwestern part of the basin which has been described, and comprising such important centers as Komárom, Győr, Bratislava, and Pápa. This area, however, is more a center of sugar-beet production than of corn production.

Győr (Raab) is one of the important centers in the Little Alföld and lies on the Raab River. To the westward of the city the land is flat and agriculturally rich. This is not a typical corn growing country, but the corn, chiefly of the flint type, is heavily manured with each planting and is well cultivated. The main crops produced are sugar beets, wheat, rye, and potatoes.

VARIETIES OF CORN AND METHODS OF PLANTING

During the last 15 years rapid strides have been made in central Europe in the selection and breeding of varieties of corn which particularly suit the needs of the grower; notwithstanding this fact, the corn grown on the peasant's farms can rarely be separated into any other classes than dent, flint, fodder, and the Italian varieties known as Cinquantino and Pignoletto, both of which have characteristics that relate them to flint. Among these varieties some have white, some yellow, and some red kernels, ranging in character from the large, soft kernel to the more compact, deeply set grain.

Information compiled in 1921 by J. Jablonowski[3] has been depended upon to furnish information concerning the history of corn-growing in Hungary. The original corn grown in this area was a variety of dent, having soft yellow kernels. Crossings of this "Hungarian maize" with such American varieties as Prairie Queen, Farmers' Favorite, King Philip, Iowa Gold Mine, Wisconsin Early White, Leaming, etc., have produced certain distinct varieties, which are now planted throughout the region.

Probably the chief variety in Hungary is Bánkúti, a dent corn first developed in the town of Bánkút, in the southeastern part of Hungary, near Mezőkegyes and Békéscsaba (pl. 4, A). According to Doctor Jablonowski, this originated in a cross between Prairie Queen and the native dent, which was followed successively by crosses with Bristol and Golden Beauty. The development of this variety, owing to the efforts of Ladislaw Baross de Bökényi, led to a dent corn of extremely high quality, comparable with any of the best varieties of the type in the United States. This corn ripens early, has well-proportioned ears, and yields by weight about 80 per cent of shelled corn and 11 per cent of cob. The kernels are orange-yellow, hard, deeply set in regular rows varying from 18 to 20 to the cob and bearing from 52 to 64 kernels to the row. This plant is of very sturdy growth, grows from 9 to 12 feet high, and is succulent, remaining for a considerable period green and suitable for forage.

The most widely grown type of flint corn, known as Hungarian Flint, has hard, white, loosely set kernels. Its chief subvariety is known as Székély 8-row. The flint corns are not easily distinguished from one another by actual varietal names, but the natives speak of them as the "yellow," the "100-Day," the "White," and the "small-kerneled."

Of importance also are the long-eared yellow flints, some of which are fairly pure crosses between the native flints and Longfellow. A crossing between Longfellow and Pignoletto, an Italian type, has resulted in the production of an excellent close-grained, hard-kerneled variety. Throughout the Little Alföld, or northwestern portion of the plains, extending into Czechoslovakia, is found a yellow small-eared flint corn, the plants of which grow to a height of only 4 to 4½ feet and bear two ears.

Throughout the southern part of Hungary is found the Italian variety Pignoletto, a useful corn ripening early and producing a short ear with fine, hard, closely set, red kernels. Many crosses have been made between this corn and the Hungarian types, as

[3] JABLONOWSKI, J. THE EUROPEAN CORN BORER AND ITS CONTROL IN HUNGARY. Abstracted by W. R. Walton and J. A. Wade. 28 p. [Washington, D. C., 1926. Mimeographed.]

A
B
C

well as between it and certain American varieties. The best cross between Pignoletto and the American variety Prairie Queen is called Puiyi, or the rose corn, and was developed first in the region around Hódmezővásárhely. Another common variety, generally and often confused with Pignoletto, is Cinquantino, an Italian corn of similar characteristics, but having kernels of a yellow-orange color.

In most cases the writers found it impossible to assign a distinct varietal name to a corn selected for observation. The merging of one variety into another was often the basis for a new name, local in character, having no particular scientific foundation, and often used to designate many subvarieties of corn. In Hungary and Yugoslavia, on large estates where careful corn breeding is done, definite records are available concerning a particular variety, but the varietal name used by the proprietor does not aid in the general separation of varieties grown outside this restricted territory.

The outstanding variety grown in the Yugoslavian corn belt is known as Rinna Dent, and is a large, well-formed, golden-eared corn. This corn is the result of the acclimatization and crossbreeding of native varieties with several American varieties. The growth of the plant resembles that of the Bánkúti variety.

Flint corn, with the exception of the small-eared Italian varieties, is seldom grown in the center of the corn belt. The change in predominance of dent corn over flint corn takes place from south to north, the flint corns entirely superseding the dents in the corn areas of Slovakia.

Sweet corn, in the American sense, is rarely grown in the central European plains except where seed may have been brought over by returning emigrants or introduced for experimental purposes. There has been no systematic effort to breed this type except at some of the experiment stations in Slovakia, and when a variety of corn, translated as sweet corn, is encountered in the central European plains the reference is usually to the early-maturing corn grown for human consumption throughout this region. This corn was evidently originally a type of flint, the ear varying from 5 to 10 inches in length and having 8 to 12 rows of large, loosely set, white kernels. It varies greatly in quality, and one acquainted with some of the American varieties of sweet corn does not enjoy its flavor or texture.

Fodder corn is grown extensively; it is closely sown and is cut and fed while green. Silage, as Americans understand it, made in silos, is rare, although since the World War it has become a greater source of forage than previously.

Silage, in the native sense of the word, is a mixture of forage beets and fodder corn, cut up, sprinkled with salt and water, and left to ferment in a large pit dug in the ground and covered over like a mound. Occasionally fodder corn is sown thickly, and the plants are cut while fairly green and cured as hay.

Pop corn is also grown in the central European plains and is of the same type as that commonly seen in the United States. It is prepared for consumption in the same manner as in the United States, and is sold during the winter by peddlers at street-corner stands.

In the center of the corn belt, corn is planted from the end of March to the beginning of May, the time depending upon the locality and the season. Most of the crop in the south is planted during the first

two weeks of April, and in the northern section of the country about the first week of May. All methods of planting are in use, from the most modern to the most primitive, but on the better farms there are two definite systems. According to one system the distance allowed between rows is 28 inches, and the plants are grown in hills 1 foot apart, with four plants to a hill. According to the other system the corn is drilled in rows 2½ to 3 feet apart and, after the third spring cultivation, the plants are thinned so as to grow from 4 to 7 inches apart. Although the larger part of the labor is performed by hand, the fields in general are very free from weeds.

The harvest occurs between September 15 and October 15. Usually the corn is husked in the fields; the ears are then carried to the farm, graded, weighed, and stored in cribs until shelled in the latter part of winter or early in the spring. The stalks are cut shortly after the harvest and are stacked in immense piles to be used for fodder, bedding, and, in the more southern regions, as a valuable item of fuel.

THE CORN BORER AS A NATIVE OF THE CENTRAL EUROPEAN PLAINS

Thanks to the painstaking effort of J. Jablonowski, director of the Royal Hungarian Entomological Experiment Station at Budapest, much valuable information concerning the corn borer, as an inhabitant of central Europe, from the time its presence there was first recorded until the outbreak of 1915-1917, has been collected and is in the possession of the Bureau of Entomology at Washington.

ORIGINAL HOST PLANTS

A study of these data leads to the belief that the corn borer, which has almost a strictly one-generation seasonal history throughout this corn area, became a permanent source of danger to the prosperity of corn soon after the increase of the planting of this crop as an important staple in central Europe. It is possible that the borer was originally confined to plants of the grass family, although it is equally logical to assume that the original host was wild hops. In the central European plains the insect depended for its existence chiefly upon three plants—broomcorn millet (*Panicum miliaceum*), hops, and hemp, which are mentioned in the earliest published accounts as its chief hosts. With the increase in corn production the preference of the borer for maize became more evident, and first attracted widespread interest through the serious outbreak in 1879. At the present day the transition to corn might be characterized as practically complete, so favorable has the insect found this introduced host.

To-day the corn borer has practically abandoned hops in the hop-growing area of northern Bohemia, although in former times it repeatedly caused severe damage to this plant. This is also true of hemp, and in large areas of hemp which have been scouted an infestation could rarely be found. The use of millet as a true host plant, however, still assumes an economic character in certain regions. (See section devoted to infestation in millet.) But, in general, corn carries the bulk of the infestation in whatever area is considered in these investigations.

The picture of the corn borer in its present environment is more complete when one considers the fact that the heaviest larval con-

centrations are now found in typical corn regions, such as southern Hungary, northern Yugoslavia, western Rumania, and the valleys in Transylvania (now a part of Rumania).

SEASONAL HISTORY

The mature larvae which have survived the winter in the central European plains begin to pupate in the latter part of May, the first pupa observed in 1923 in these investigations having been found in the field on May 18, the first in 1929 on May 20, and the first in 1927 on May 23.

Table 3 presents the average dates of several outstanding events in the seasonal history of the European corn borer, as observed in the years 1924 to 1927, inclusive, in Hungary and Yugoslavia, and Table 4 the average progress for the same years of other features of seasonal development as related to selected dates of the developmental season.

TABLE 3.—*Average dates of occurrence in the field of certain events in the seasonal history of the European corn borer, 1924 to 1927, inclusive, in Hungary and Yugoslavia*

Feature	Average date of occurrence
First moth	May 20
50 per cent of moths	June 17–26
Last moth	July 10
First egg mass	June 6–9
50 per cent of egg masses	July 1–6
Last egg mass	July 16–20
First hatch	June 10–16
Maximum of hatch	June 20–25
Last egg observed	July 20–27
First larva	June 11–17
1 per cent of larvae attain fifth instar	June 17–23
50 per cent of larvae attain fifth instar	July 7–9

[1] For this and the next observation of each in 1927 is not included in the average, the observations having been made after July 11.

TABLE 4.—*Average progress of features of the seasonal development of the European corn borer in the central European plains, as related to selected dates of the developmental season, 1924 to 1927, inclusive*

Date	Percentage of pupation	Percentage of emergence	Oviposition observations per 100 plants	Percentage of egg mass
May 20	0			
25	1			
30	4			
June 1	5	0.4		
5	10	1.5		
10	20	7.9	4	
15	35	17.7	7	
20	50	26.6	16	
25	70	42.2	28	
30	85	56.3	38	
July 5	97	68.4	80	
12				
14	97	84.7	25	
20	99	88.4	9	
25				
30		100.0	5.4	
Aug. 1				
5				
10				
15				
20				
25				
30				
Sept. 5				

In studying the normal progress of pupation, from May 29 onward as shown in Table 4, it will be seen that during the first 15 days of the period the advance is very slow; in the interval from June 4 to June 9 the number pupating is almost doubled. Pupation continues during a period of two months and is nearly completed in the third week in July. There are, however, larvae which do not pupate until very late in the summer, more especially those which have been in the cold, moist centers of immense corn piles.

Although the four years of observation show on the whole an evening up of development toward the end of the season, the course of development has varied in different seasons. Fifty per cent of the larvae in the field had pupated approximately one week earlier in 1924 than was the case in 1925, 1926, and 1927, but emergence was completed in 1924 one week later than in 1925 and 1927, and two weeks later than in 1926. The first adult observed in 1925 was recorded on June 2, and the first in 1926 and 1927 on June 12. Although emergence proceeds more rapidly than pupation, it is spread out over a period of more than a month and a half, extending from June 4 to July 24. The sharpest rise in emergence normally occurs between June 19 and June 29. Emergence is never naturally complete as early as July 24; there is always a small percentage of late-pupating individuals emerging throughout the summer, even to the middle of September.

Owing to the fact that such data on oviposition as could be collected had to be taken from field observations, it has been much more difficult to express numerically the deposition of eggs on successive dates than to give similar expression to pupation and emergence. There was no opportunity to run cage experiments to determine the egg-laying period, and the best that could be done was to count the egg clusters per 100 plants in the field. The resulting figures, included in Table 4, are therefore only approximate.

In 1924 the first egg cluster was observed on June 6. No separate observation of this character is available for 1926; on June 24 of that year there were already present in the field a total of 12.7 clusters per 100 plants. The maximum number of eggs in the field was recorded on July 9 in both 1925 and 1926, whereas in 1927 this feature was observed one week earlier. Eggs are found in the field late in the season; in 1925 the last known cluster was observed September 27.

Since in these investigations detailed study of the life history of the corn borer was considered secondary in importance to the determination of the intensity of infestation by the insect in various regions, the actual development of its various stages could not be observed as closely as would have been the case had the investigators been situated at a permanent laboratory, with a series of controlled experiments under their observation. Data on the progress of larval development by instars were obtained by collecting each day as many larvae as possible while making plant dissections to determine the larval population. The larvae collected were preserved in chloral hydrate, in vials which were sealed and saved. At the end of the season, when the investigators had returned to the field laboratory at Hyères, France, all this material was carefully dissected for data on parasitism, and the stage of development of each larva was noted.

Although considerable information has been collected as to the time of appearance of each instar under field conditions, it seemed

better to present in Table 4 the progress in the appearance of the fifth instar. Those data are also available as a basis for determining the approximate time at which commercial damage may be expected to appear.

The first larvæ usually appeared between the middle and the end of June and attained the fifth instar by the middle of July. A most interesting fact brought out is that 50 per cent of the individuals reached the fifth instar in the first week of August. Ninety-five per cent or more had reached this stage in the last week of August. Toward the latter part of September the larvæ had in nearly all cases ceased feeding and had entered the diapause, and remained in that state until pupation in the following spring.

NUMBER OF GENERATIONS PER YEAR

Since one of the most important purposes of this project is to determine the number of generations of the borer occurring annually in all regions visited, whatever time could be spared from the collection of systematic data in the central European plains was devoted to trips through areas thought likely to be either in the transition zone or the 2-generation zone.

The importance of knowing what seasonal rhythm[1] is natural to a particular environment has been discussed in a previous paper by the senior writer (17). In the work upon the distribution survey, reported at the beginning of this bulletin, particular attention was given to the collection of data which would show the type of the seasonal cycle of each region visited. Besides these general observations, detailed data upon this feature of the project have been collected in the central European plains and are presented in Table 5.

TABLE 5.—*Numbers of specimens of the European corn borer examined in 1926, 1927, and 1928, in selected regions of the central European plains, with percentage of pupation on and near, indicating geographic subdivisions of the second generation*

Year	Region	Examined	Pupation
		Number.	*Per cent.*
1926	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
1928	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
1927	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]
	[illegible]	[illegible]	[illegible]

It should be stated here that the number of specimens examined upon which the percentage of pupation is based were taken from the routine field data, so as to give as accurately as possible the true percentage of those that were forming a second generation for the year named, by pupating or unmistakably preparing to do so. These

[1] The term rhythm as used throughout this discussion means that tendency of the insect which leads to greater or less frequency of the activities mentioned as a change takes place in the environment.

percentages therefore represent for the several named years the relative effect of the various temperature-moisture combinations in producing exceptional individuals of the second generation under the environmental conditions normally present in this almost strictly one-generation area.

All recent data collected from the field follow the conclusions drawn by the senior writer in two previous papers (1, 2), and these new data will be discussed in a paper to follow. Since the publication of the second of those papers definite information has been made available that southern Yugoslavia and an adjacent portion of Greece is a strictly two-generation region, and that, in Germany, Baden and Bavaria are strictly one-generation regions.

Information has been collected by the Japanese beetle investigators in the Orient which indicates that three generations of the corn borer a year occur in southern Japan, two in central Japan, one in northern Japan, and one and a partial second in Chosen (Korea).

Suggestions have been made that the individuals in the two-generation area in the United States which have a life cycle different from that of the individuals in the one-generation area, and somewhat different habits as to host plants, be considered as representing a distinct "biological species." Such a distinction appears undesirable, owing to the fact that related insects are ordinarily not considered separate "species" when they interbreed freely, producing fertile offspring, and when many individuals show intergrading characteristics. In the case of the corn borer such groups of individuals can therefore preferably be considered as biological varieties or strains.

It has been shown elsewhere by the senior writer (1, 2) that the differences in life habits of the one-generation and two-generation strains in Europe are correlated with certain differences of equipment, and that it is not improbable that these differences in the economies of the two strains have resulted from the reaction of the insect to different environmental conditions at some time in the past history of the species, in accordance with hypotheses which he presented. Experimental tests have shown that the respective habits of both the one-generation and the two-generation strains persist when the insects are artificially transferred to new climatic conditions, and that this persistency has been maintained in the United States experimentally for a period of eight years. However, conditions in Europe, as well as experiments in artificial breeding, lead to the belief that environmental circumstances, such as short summer seasons and certain conditions of precipitation, may eventually result in changing the seasonal cycle of the two-generation form in the direction of a one-generation habit, and vice versa. How much time may be required to accomplish this result is, of course, entirely problematical.

EXTENT AND ECONOMIC RESULTS OF INFESTATION

In discussing the infestation of various crops by the corn borer, both as to extent and as to economic results, the writers do not attempt to present detailed data collected year by year for the separate fields, but to give a general view of the possible injury to the crop as a whole, and to analyze to some extent its economic results; discussing in turn the infestations of corn, of other crops of economic importance, and of certain miscellaneous plants, some of economic value and others of interest only in some other respect.

CORN

In Table 6 are presented, by localities in the country chiefly affected, data on the more important features of infestation of corn in the years during which were conducted the researches here described. In succeeding paragraphs special features of the infestation will be discussed.

In Hungary and Yugoslavia a very interesting fluctuation in the intensity of infestation has been observed. A survey of the infestation at the time the corn ripened was made in approximately 300 fields in each of the four years, 1924–1927. The data in Table 7 are based upon the examinations made in 1,118 fields during the 4-year period.

TABLE 7.—*Statistical data relating to the infestation of corn by the European corn borer in 1,118 fields in Hungary and Yugoslavia, 1924–1927*

Group	Proportion of fields in group				Average [illegible] per 100 plants			
	[illegible]	[illegible]	1926	1927	[illegible]	[illegible]	[illegible]	[illegible]
Larvæ per 100 plants	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Number*	*Number*	*Number*	*Number*
0 to 49	70.4	9.2	8.9	66.3	21.0	17.3	17.1	22.7
50 to 99	4.4	4.6	7.4	18.7	79.3	78.5	72.0	71.1
100 to 199	13.6	16.4	13.2	17.6	139.1	153.0	136.6	139.2
200 to 299	5.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
300 to 399	3.9	41.0	20.6	6.2	665.1	665.4	626.0	625.1
400 to 899	1.5	16.2	15.7	1.5	794.1	719.3	730.2	784.2
900 to 1,199	1.5	.....	8.7	1.1	1,070.0	.....	1,036.4	1,065.2
1,200 to 1,499	.9	1.7	5.2	.3	1,384.0	1,345.0	1,316.1	1,407.3
1,500 to 1,799	.....	.5	2.0	.....	.....	1,680.0	1,616.4	.....
1,800 to 2,099	.6	.....	1.2	.....	1,960.0	.....	1,934.3	.....
2,100 to 2,399	.....	.....	.8	.....	.....	.....	2,270.0	.....

Group	Proportion of plants infested[1]				Average		
	[illegible]	[illegible]	1926	1927	Proportion of fields in group	Larvæ per 100 plants	Proportion of plants
Larvæ per 100 plants	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Number*	*Per cent*
0 to 49	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
50 to 99	32.9	42.6	45.6	33.8	8.6	74.4	39.7
100 to 199	48.8	50.5	63.3	46.1	15.2	140.2	52.2
200 to 299	66.1	64.2	86.8	60.7	5.7	246.7	69.1
300 to 399	85.1	78.3	93.4	75.5	17.9	635.2	83.1
400 to 899	93.6	91.9	98.6	91.4	9.5	706.9	93.4
900 to 1,199	100.0	.....	98.9	98.5	2.6	1,084.6	98.1
1,200 to 1,499	100.0	100.0	99.3	99.7	2.0	1,355.2	99.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
1,800 to 2,099	100.0	.....	99.9	.....	.2	1,960.0	100.0
2,100 to 2,399	.....	.....	100.0	.....	.2	2,270.0	100.0

[1] Average for the [illegible] fields in the four years, 93.86.

[2] Average percentage of plants infested in the [illegible] years, 0.86.

The character of this fluctuation is clearly shown by the distribution of the fields in the different groups of larval population per 100 plants. From a minimum in 1924, when only 8.4 per cent of the fields examined had a larval population of 300 or more borers per 100 plants, a figure of 50.8 per cent was reached in 1925. Although in 1926 a smaller number of fields were in this category (37.2 per cent), the intensity of the infestation was actually increased, as is shown by the greater number of fields in the groups of higher

TABLE 6.—*Principal features of infestations of corn by the European corn borer, 1924–1927, in regulated townships in the area of heaviest infestation*

larval population. The average larval population and percentage of plants infested were also higher in 1926 than in 1925. In 1927 the insect was so reduced in numbers that its status was almost comparable to its status in 1924.

Figure 2 represents graphically the average of larvae per 100 plants for each of the four years concerned, without reference to the separate groups, and Figure 3 in a similar manner the average percentage of infestation of the plants. The data here represented are not given in Table 7.

It may be of interest to illustrate further the intensity of the infestation in the most severely infested fields in the central Euro-

FIGURE 2.—Graphical representation of the average number of larvae of the European corn borer per 100 plants in Hungary and Yugoslavia in 1924, 1925, 1926, and 1927

pean plains. The highest larval population observed in 1924 was found in a field of dent corn at Mezohegyes, Hungary, which had 1,960 borers per 100 plants. In this field both 100 per cent of the plants and 100 per cent of the ears were infested, and 82.4 per cent of the plants were broken. In 1925 the most severely infested field, which also had a plant infestation of 100 per cent, was found in Senta, Yugoslavia, with 3,830 borers per 100 plants, and a maximum of 40 borers in a single plant. In this field, also, 100 per cent of the ears were infested, and 87 per cent of the stalks were broken. In 1926 the field of maximum infestation had a larval population of 2,360 borers per 100 plants, and a maximum of 39 borers in a single plant. The year 1927 produced no comparable "worst" field,

since the highest larval population found in a field in Mezokovesd, Hungary, was 1,427 borers per 100 plants, with a maximum of 34 borers in one plant. In 1928 the maximum number of larvae in one plant did not occur in the fields having the highest larval population, but in a field at Velika Kikinda, in Yugoslavia, 53 larvae were found in a single stalk, and 22 larvae were dissected from one ear of corn.

Although the "worst" infested fields are indicative of the possibilities of the insect in years of outbreak, it is only by a proper appreciation of their relation to the corn belt as a whole that an accurate picture of the intensity of infestation can be obtained.

Let us consider that general area which we have designated in the map (fig. 1) as the center of the corn belt, in terms of fields which during the four-year period sustained larval populations of 500 to 1,000 per 100 plants, and 1,000 and more per 100 plants.

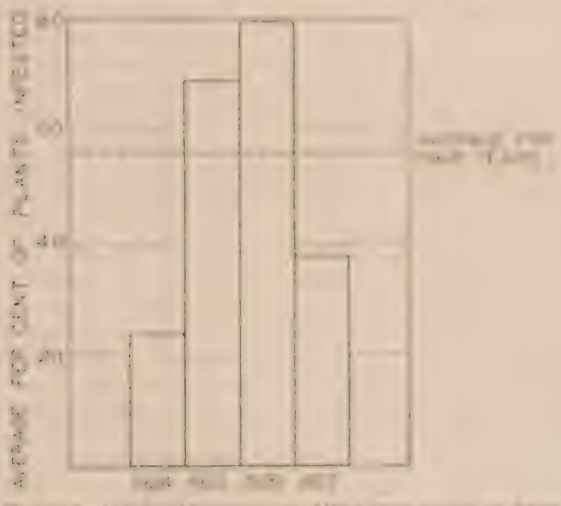

FIGURE 1.—Graphic representation of the average percentage of corn plants infested by the European corn borer in a 1,134-hectare locality in Hungary and Yugoslavia in 1924, 1925, 1926, and 1927

Since few systematic data were taken in 1924 in Yugoslavia, comparison with other years is not warranted. In the Hungarian portion of this district, however, 21 per cent of the fields had populations of from 500 to 1,000, and 5 fields, or 8.8 per cent of the fields in this locality, had populations of 1,000 borers or over.

In this discussion of the relationship between heavily infested fields and the other fields considered, attention should be given to the figures in Tables 6 and 7. The presence of a large percentage of heavily infested fields in this region is particularly dangerous economically, since the fields are larger here than in other portions of the corn-growing area, and more of the tillable land is devoted to the growing of corn.

In 1925, in the center of the corn belt, 72 per cent of the fields had populations ranging between 500 and 1,000 borers per 100 plants, and 3 per cent had 1,000 or more borers per 100 plants. These data, as well as those for the following years, include all fields from both the Hungarian and Yugoslavian portions of the center of the corn belt.

In 1926 71 per cent of the fields in this area had populations of from 500 to 1,000 borers per 100 plants, and 22 per cent of the fields in the center of the corn belt had over 1,000 borers per 100 plants.

As indicated by the remainder of the data, the striking reduction observed in 1927 was widespread, and correspondingly only 10 per cent of the fields in this district had populations of between 500 and 1,000 borers per 100 plants, and 2 per cent of the fields had 1,000 or more borers per 100 plants.

Conditions for the entire corn belt are accurately pictured in Table 7 for the 4-year period, and the towns in the center of the corn belt having high larval populations are shown in Table 8. It is expected that a further analysis of intensity of infestation will be made at the completion of the 5-year period and discussed in a separate publication.

Although it is highly essential to collect information showing the seasonal development of the corn borer, its habits, and the possibility of infestation, the most critical phase of the investigation demands concise information on the actual decrease in yield resulting from the activities of the insect. Unfortunately, because of imperfect methods, it is not possible at the present time to represent by a definite figure a certain degree of damage directly attributable to the insect. One can see the damage, however, and by comparison with the normal yield in a certain locality obtain an idea as to the probable importance of the role of the insect in reducing the yield in a given season below the expected crop. For example, a field could be damaged by high winds in the absence of the corn borer, but where the insect is abundant the same wind undoubtedly would produce greater damage; yet to assign a definite value to the relationship existing between larval population, high winds, and ultimate damage would be next to impossible. Furthermore, actual estimates of injury caused by the feeding of the borer would not tell the whole story, since no consideration would be given to the effect of forced maturity upon the yield of grain. Forced maturity is frequently found in areas of high larval concentration, and decreases the feed value of both stalks and ears if they are to be used as fodder. These effects may be further intensified by conditions of drought.

The estimation of loss due primarily to the corn borer is often complicated by the presence of various fungi, which become a more pronounced factor in years favorable to their development.

The crop loss in a field planted solely for the production of selected seed may be roughly estimated by a count of the number of ears which must be discarded as a result of injury by the borer. The problem becomes more difficult, however, in the majority of fields in the central European plains, where corn is grown for both grain and fodder.

In 1924 and 1925 the investigators attempted to arrive at a figure which would approximate the crop loss sustained in various localities. It was felt, however, that not all of the loss as estimated could be directly ascribed to the attack of the corn borer, although the results were useful in picturing the conditions present in the fields having high larval populations.

It should be remembered that estimates of loss which are based upon the money value of the crop to the farmer in terms of expectancy of a certain yield should not be confused with the amount of

actual damage inflicted upon the crop by the insect. It is naturally unfair economically to estimate losses upon such a basis, because this method tends to hide the fact that a fair yield may have resulted in spite of very evident damage by the insect. Throughout this discussion the authors have attempted to indicate clearly this difference and to point out every case where the estimate has been based upon the supposed money value of the crop, had not the insect been present.

In 1924, at Mezőhegyes, in south-central Hungary, the actual loss resulting from the feeding of the corn borer upon the grain was determined by accurate counts. Two fields were of particular interest. In one, in which the average larval population was 1,460 per 100 plants, the grain suffered a direct loss of 92.4 per cent, whereas the yield from this field was only 7.4 per cent of what was expected. In another field, in which the larval population was 1,960 per 100 plants, the direct loss of grain was 55.2 per cent. In this locality the average direct loss of grain for the season, based on a count of 10 fields, amounted to 4.9 per cent, while the total estimated loss in yield caused by the ravages of the insect was 10.8 per cent. In 28 fields examined, constituting the entire district, the loss caused by the insect was estimated at 23.9 per cent of the value of the crop—a loss higher than corn under normal conditions is expected to suffer in that region. One field of the group was so badly damaged that no harvest was attempted, and the stalks were used for compost.

During the years in which examination was made commercial loss was noted in all sections of the main corn-growing region, and particularly in the corn-belt center represented by the locality of Mezőhegyes. In 1924 attempted estimates showed that Bánkút, lying to the northward of Mezőhegyes and in the main corn belt, suffered a direct loss of 18.4 per cent of the crop, and Novi Sad, Yugoslavia, an average of 18.9 per cent, both estimates of losses being above the normal loss expected.

These figures indicate the possibilities of the insect in inflicting damage, but they should be considered with the qualification that this damage occurred in a year when an "outbreak" could not be said to have occurred. In the year 1925, when the investigations were extended and the insect had increased in abundance, the possibility of severe attack became more evident. Three noteworthy cases occurring in the heart of the corn belt in Yugoslavia may be mentioned, in all of which the corn crop was totally destroyed. (1) A field at Senta, in northern Yugoslavia, near the borders of Hungary and Rumania, with a larval population of 1,342 per 100 plants, was totally destroyed; (2), one at Veliki Bečkerek, with a larval population of 1,142 per 100 plants, was similarly affected; and (3) one at Velika Kikinda, with a similar larval population of 1,074, produced no corn. In the same year very high average losses also occurred in several districts, noteworthy among which were the average losses in money value of 45 and 40 per cent for the districts of Senta and Veliki Bečkerek.

The damage in this season was further increased by high winds, which broke over the infested plants before their maturity. The importance of this factor, particularly in a season of high infestation, was illustrated in several fields. In one field of dent corn near Temesvar,

17 miles north of Novi Sad, Yugoslavia, having a larval population of 1,450 per 100 plants and a plant infestation of 100 per cent, 74.3 per cent of the plants were completely broken over. (Pl. 5, A, B.) In another field at Mezőhegyes, Hungary, where severe windstorms occurred, an average of 43 per cent of the plants were broken in 9 fields of flint corn, having a larval population of 462 per 100 plants and a plant infestation of 66 per cent; and on 21 fields of dent corn, with a similar larval population of 503, the percentage of broken stalks was 66. A third striking illustration was found at Pécs, Hungary, where an average of 73.8 per cent of the plants were broken in 4 fields of dent corn, having a larval population of 50.8 per 100 plants.

To bring out further the extreme possibilities of damage by corn, let it be assumed that where the larval population rises above 400 borers per 100 plants, and the ear infestation rises above 25 per cent, there is danger of commercially important damage. This assumption is based upon experience, both in North America and in the central European plains, which indicates that this intensity is the "danger point," above which appreciable loss will normally occur. However, in such areas as Baden, Germany, losses may occur with larval populations as low as 100 borers per 100 plants. The assumption here used is therefore arbitrarily made for conditions found existing in the central portion of the European corn belt.

By referring to Tables 6 and 7 it may be seen that, on the basis of a 4-year average, which may be taken as a tentative normal expectancy, 33.6 per cent of the fields in the central European plains will always be in danger of commercial damage, and that in the majority of cases these fields will be found in the vicinity of Szabadka, Szeged, Békéscsaba, and Baja, in Hungary, and of Novi Sad, Pančevo, Veliki Bečkerek, and Velika Kikinda, in Yugoslavia. It may also be expected that these localities will have an average minimum of 78 per cent of the fields infested. Judging this condition from the standpoint of ear infestation only, there are to be added the towns of Kaposvár and Nagykanizsa, in Hungary, and Stari Bečej, Subotica, and Sombor, in Yugoslavia. With the data at present available it is not possible to indicate definitely what degree of commercial damage may be expected in connection with various intensities of infestation nor what percentage of fields in different localities would sustain this damage.

If the reader uses the method of scrutiny previously outlined for each of the four years under consideration, he will gain a clearer picture of the possibilities of damage by the corn borer in its native home.

OTHER CROPS OF ECONOMIC IMPORTANCE

Previous to the time when considerable attention was directed toward the study of the corn borer very little information was available as to the complete list of host plants of the insect in the central European plains. Doctor Jablonowski in his manuscript records wild and cultivated hop, hemp, corn, broomcorn (*Sorghum vulgare*), broomcorn millet (*Panicum miliaceum*), cotton, sunflower, mustard, oats, and barley, and an incidental infestation was discovered in grapevines.

The known distribution of the corn borer has been thoroughly discussed by Caffrey and Worthley (*9*), by whom attention was

drawn to the fact that the insect is normally an inhabitant of many regions beyond the limits within which corn is grown, and has been and still can be a pest in these regions.

For the purpose of this bulletin the discussion has been confined to the regions in which the authors personally made observations, which will be discussed separately.

MILLET

Several reports in the Russian literature mention the fact that the corn borer has destructively attacked millet (*Panicum miliaceum*) and that outside the corn-growing area in Russia the insect is a continuous inhabitant of this plant, doing more or less damage.

A series of counts to show the infestation of millet were made by taking a group of stubble, 100 to a row, the initial counts being taken about a yard from the base of the first row of millet stacks and the others at a distance of a pace toward the next row. The average of the counts taken in the first row of stubble next to the stacks showed an infestation of 23.4 per cent, and the infestation in the other rows was found to be 16.7, 7.5, and 1.4 per cent, respectively. The average infestation for all stubble in the counts was 10.3 per cent. Several millet stacks were lifted from the ground, but no larvae were discovered in the stubble underneath them.

During the season of 1925 the investigation of the infestation of millet at Mezohegyes was continued, and from the examination of 1,400 plants an average stem infestation of 24.2 per cent was found, with a larval population of 39 borers per 100 plants. This was the highest infestation observed in millet. During the season of 1926 counts taken in the same locality showed that the stem infestation had dropped to 2.8 per cent.

In the season of 1924 counts were made at Mezohegyes in a heavy field of millet which had been cut for about a week. At the time of observation the crop was being carried to the barns. (Pl. 6, A, B.) Five separate counts of 200 plants were made in each of the seven rows, or a total of 7,000 plants, from which the average infestation was found to be 8.1 per cent. A particularly interesting feature of this infestation in millet was that immediately after the stems were cut the larvae left them and migrated to the stubble, the latter being 2 or 3 inches high and affording the larvae excellent quarters. This migration was strikingly evidenced by the fact that near the rows of stacks the stubble in many spots was topped by fluffy white balls of frass, indicating the presence of the larvae. As one walked out into the field toward another row of stacks the quantity of these frass balls decreased; their presence again became more marked as one approached the next row.

Fields of millet were examined in other sections of the country, but the infestation found was very slight. The results of counts made during the season of 1926 will give an idea concerning the insect's abundance in this plant; at Szombathely, one plant out of 500 was infested; at Székesfehérvár, none out of 100 examined; at Nagykanizsa, none out of 400 examined; at Bánkút, 1.8 per cent; and at Szeged, an infestation of 16.8 per cent.

BROOMCORN

Although the infestation in broomcorn is never so high as in corn, fields have been examined where the infestation in the butts attached to the cut heads was so high that exportation of the heads would be dangerous if not preceded by some insecticidal treatment.

During the season of 1924 two areas in Hungary, those about Debreczen and Mezőhegyes, were carefully examined for data on broomcorn infestation. The average infestation for the first region was 5.4 per cent of the plants, with an average infestation of less than 1 per cent of the heads alone. At Mezőhegyes an average infestation was found of 17.3 per cent for the plants and 9.6 per cent for the heads. At Bánkút, a short distance from Mezőhegyes, the broomcorn was found to have 20.9 per cent of the plants infected, and 7.7 per cent of the heads. The maximum infestation of broomcorn for this season was found at Bánkút, in one field where there was an average infestation of 54.8 per cent of the plants and 16.4 per cent of the heads.

In 1925 these investigations were continued, and at Mezőhegyes an average infestation of 26.4 per cent was found in broomcorn plants. The larval population in 100 plants was 174, while in the cut heads only 8 larvae per 10 pieces were found. At Bánkút in this year the infestation was 26.4 per cent of the plants, with a larval population of 26 per 100 plants, while the cut heads were found to have 7 larvae per 100 pieces. Counts were made also at Makó, near Szeged, disclosing an infestation of 29.5 per cent of the plants and a larval population of 78 per 100 plants.

The infestation of 1926 was much lighter than were the infestations in 1925 and 1927; at Mezőhegyes only 4.2 per cent of the plants were infested, with a larval population of 5 per 100 plants. No higher infestation than this was found in Hungary during the season. Counts were taken in Sombor, Subotica, and Velika Kikinda, in Yugoslavia, and the infestation at these places was found to be correspondingly low, being 0.7 per cent, 5.7 per cent, and 0.2 per cent, respectively. In a count of heads made at Sombor 4.3 per cent were infested, while at Subotica the average infestation was 3.2 per cent. In each infested tip only one larva was found.

An examination of 7,844 broomcorn plants in the central European plains in 1927 showed that 0.88 per cent were infested with an average of four borers per 100 plants, and that 0.06 per cent of the plants were broken.

Larvae of the corn borer may be found throughout the area where broomcorn is grown, but the infestation is generally very light. (Pl. 7, A, B.)

HEMP

Although hemp has been mentioned repeatedly in the literature as one of the oldest host plants of the corn borer, it is rarely found infested at the present time in the central European plains. (Pl. 6, C.)

From the data collected during the four seasons of investigation it may be concluded that the corn borer offers no hindrance to hemp cultivation. The highest infestation of hemp in 1924 to 1927, inclusive, was observed at Mezőhegyes, Hungary, in 1924. The data for this infestation were taken on September 27, when 40 per cent of

A
B

A.—Field of millet at Mezohegyes, Hungary.
B.—Loading millet at Mezohegyes.
C.—Mature hemp at Mezohegyes.

A—
B—

A
B
C

the crop had already been cut for drying. The average infestation, based upon counts of 9,500 plants, was found to be 14.5 per cent, with a larval population of 17 per 100 plants. The particular field where the count was made was planted with female hemp, drilled in rows, and later thinned to 4 or 5 inches between plants, so the hemp at the time of maturity appeared like an immense growth of reeds. The infestation of this field was undoubtedly an exception, since no other such infestation was discovered. Hemp is usually planted in the first week of April, and harvested between September 15 and September 25. The male plant matures more quickly than the female, and the plants of this sex had all been harvested and hauled to the factory a week before the infestation was determined.

In 1926 many examinations of hemp were made, the highest infestation, based upon an examination of 10,000 plants, being found again at Mezőhegyes, but averaging only 2.2 per cent.

In 1926 counts of hemp were made in Yugoslavia, but the infestation by the corn borer was so scattered in character that the average for the area would be even less than one-half of 1 per cent. These data are all the more interesting when it is considered that they were taken, in all cases, where the larval population in corn was averaging from 700 to 1,300 borers per 100 plants.

HOPS

Doctor Jablonowski states in his manuscript that the corn borer was very dangerous to the cultivation of hops during 1879 and 1880 in Bohemia, in 1886 in Bavaria, and in 1893 in Alsace. The notes concerning the outbreak of 1879 in Bohemia are striking as an indication of the intensity of the attack. In the heart of the finest hop-growing region of that country, at Rakonitz, the larvae were so abundant that the harvest for that season was entirely useless, and in the districts of Saaz, Laun, and Podersam every hop grower suffered losses from the ravages of the insect. The larval population at that time may be appreciated from the fact that from 15 to 30 borers were found in each vine. Infestation in hops, when severe, is particularly destructive, owing to the fact that even two or three borers in a vine which is approaching maturity, i. e., at the height of the blossoming period, so weaken it that the blossoms are very much reduced in size and poorly formed, and many fall to the ground before harvest.

In 1925 a trip was taken throughout this region in Bohemia, where formerly the insect had been such a pest to the hop plant, and the important centers of Domousice, Roudnice, and Zatec (Saaz) were visited on August 8, 9, and 10, respectively, just at the beginning of the hop harvest. Many fields were examined, but only 23 larvae, all in the fifth instar, were collected for the entire area. (Pl. 8.)

VARIOUS SORGHUMS

At the time of a visit to Bánhát, Hungary, on September 28, 1924, a 2-acre field of Jerusalem was examined and found to have an infestation of 3.0 per cent, with an average population of 1.1 borers per plant. None of the plants were broken over as a result of the feeding of the larvae, which at that time were mature, although

in one stalk three borers were found. At the time the feterita was full-grown and the seed heads were drying, the injured plants in most cases could be recognized by their undeveloped heads.

While the senior writer was at Temerin, Yugoslavia, on September 9, 1925, an opportunity was given him to inspect a 3-acre planting of kafir corn on the estate of Mr. Popovitch. The planting was still green, and just beginning to mature. Several hundred plants were examined, and only one stalk was found infested. The corn in this locality averaged over 95 per cent in plant infestation, with 980 larvae per 100 plants. Practically no sorghum is grown on a commercial scale anywhere in the central European plains, although it is planted occasionally for experimental purposes.

Considerable effort was expended in 1926 to discover possible sorghum plantings through the ministries of agriculture of Czechoslovakia, Hungary, and Yugoslavia, in order that data might be collected showing the relation of the insect to the culture of this crop. In no case was any information available on the subject.

During the course of the scouting trip which the junior writer made through Czechoslovakia in the summer of 1926, he was able to make a count of infestation in a species of sorghum at Brathdorn. This sorghum was locally known as "Indian millet" or "red sorghum," but its scientific name was not available. It had been imported from Russia, and experiments were being carried on in this region to determine its suitability as a fodder plant. In a plat approximately 160 feet long and 6 feet wide 1,000 cut stalks were carefully examined, and 4 were found to be infested by the borer. The stubble left in the field ranged from 6 to 8 inches in height, and in an examination of 1,000 of them 12 were found to have been infested, 4 of which contained live larvae. The corn in the same locality had an infestation of 17 per cent.

In addition to the information obtained from the experimental plantings, an examination of 1,500 sorgo plants in Székesfehérvár, Hungary, in 1927, showed a 1 per cent infestation by the borer, with a larval population of 1 borer per 100 plants. A count of 1,000 plants in a 5-acre field of feterita, 7 feet high, located near Cegled, Hungary, showed no infestation.

With the exception of these chance observations, very little information could be collected in central Europe concerning the advisability of planting sorghum instead of corn as a fodder crop. From the standpoint of the North American farmer this substitution may become an important move in the fight against the ravages of the corn borer, and it therefore seemed advisable to start experimental plantings in various regions in the central European plains. This was done, and the data obtained from such plantings in 1927 are discussed on page 39.

MISCELLANEOUS PLANTS

During the four years of investigation extensive counts were made in other crops of economic importance such as tobacco, potatoes, beans, beet tops, oats, wheat, and barley, but no infestation was discovered in any of them.

WEEDS AND OTHER PLANTS NOT ECONOMICALLY IMPORTANT

Throughout the four seasons in which the present investigation was conducted the status of the corn borer in various common weeds was observed when practicable. The infestation of all such weeds has an important relation to the effectiveness of any clean-up campaign that might be instituted.

In 1924, in the area where the infestation of corn averaged more than 50 per cent, examinations were made of species of Amaranthus, Chenopodium, Ambrosia, thistle, Rumex, and Echinochloa. The only infestation found in these was in a species of Echinochloa growing in a field of heavily infested corn, of the "peasant's-choice" type, just outside the town of Nagykanizsa, in Hungary. The field of corn was thickly grown up with this species, and in an examination of 1,000 stems 92 were found to be infested, with one borer to the stem. In the central European plants, at the time of maximum oviposition, the common weeds are not so attractive to the borer as is the corn. For example, when observations were made at Debreczen on June 10 and 11, 1924, Amaranthus and Chenopodium were only about 4 inches high, whereas corn had attained a growth of about 18 inches.

With the progressive increase of the infestation in corn in 1925 and 1926 the infestation in several of the common weeds likewise increased. Counts made at Mezohegyes, Hungary, on October 9, 1925, showed that 5 per cent of the stems of 1,400 plants of Amaranthus, all growing in a heavily infested cornfield, were infested, and that on an average there were 3.9 larvae per 100 stems. At the same time 1,000 plants of *Solanum nigrum* were examined, of which 2.5 per cent were found to be infested, with an average of 3.2 larvae per 100 plants. In the same locality many stems of Xanthium and Echinochloa were examined, but no infestation was found.

On a visit to Temerin, in Yugoslavia, on September 6, 1925, the senior writer observed a 25-acre field of heavily infested dent corn entirely surrounded by thick clumps of a species of Xanthium, the plants of which were fairly mature. One hundred per cent of the plants of corn were infested, with a larval population of 980 borers per 100 plants. Two hundred plants of Xanthium were inspected, of which 82 per cent were found to be infested, with an average of 7.4 borers per plant. In the same field a quantity of a grass belonging to the genus Echinochloa was examined, and 6.5 per cent of the stems were found infested, with an average of 1 borer per infested plant. It is the opinion of the writers that this heavy infestation of weeds was due solely to direct migration from the corn, regardless of this fact, so intense an infestation points out the necessity for extreme care in clean-up measures undertaken even in a one-generation area.

The further increase in the infestation in corn in the season of 1926 was followed by an infestation in weeds which became still more marked. Counts made in Amaranthus at the Mezohegyes, Hungary, district, on August 26, 1926, showed that 18.3 per cent of the plants were infested, while at Kaposvár, Hungary, from which no record of infestation in weeds had previously been reported, there was an infestation of 12 per cent in Amaranthus. The spread of the infestation during this season in Echinochloa was even more interesting; the infestation at Gyor was 3.5 per

cent, at Nagykanizsa, 3.8; at Szolnok, 2.5; at Békéscsaba, 0.6; and at Mezöhegyes, 7.4 per cent.

In September, 1926, counts of weeds were made in Yugoslavia. In Echinochloa an infestation of 16.6 per cent was found on September 10, at Velika Kikinda; of 17 per cent at Senta, on the 11th; of 7.8 per cent at Sombor, on the 14th; and of 7.5 per cent at Subotica, on the 17th. In Amaranthus an infestation of 8 per cent was found on September 9, at Velika Kikinda; of 18.7 per cent at Senta, on the 11th; and of 15.5 per cent at Subotica, on the 12th. In Chenopodium an infestation of 11 per cent was found at Velika Kikinda on September 9, and one of 1 per cent at Subotica on the 12th. At Subotica, on the 12th, also, an examination of Xanthium was made but no infestation was found. Trinodin, where a heavy infestation occurred in the previous year, was not visited. At Subotica a heavy growth of Polygonum was examined, but no infestation was found.

In 1927 a few examinations of weeds were made, which may be summarized by saying that 3,670 plants of Echinochloa were examined, of which 1.4 per cent were found infested, having 8.4 borers per 100 plants; of 1,420 plants of Amaranthus examined, 1.3 per cent were found infested, with 6 borers per 100 plants; of 240 plants of Polygonum examined, 1.7 per cent were infested. No infestation of weeds has been observed in the central European plains except in close proximity to corn.

NATURAL ENEMIES

PARASITES

A study of the distribution and abundance of parasites of the corn borer in the central European plains has been carried on for four years in connection with the collection of other data, and has included field notes taken in connection with various observations, and information gained from laboratory dissections of host larvae. During the spring and summer of 1924 a total of 4,400 host specimens were observed in the field. In 1925 this number was increased to 15,025, in 1926 to 29,840, and in 1927 to 36,876. Laboratory dissections of 6,516 borers were made in 1926, and of 4,911 in 1927. In the determination of parasitism by a species of Trichogramma 5,283 eggs of the borer were examined in 1926 and 10,375 in 1927.

In the central European plains only three principal parasites of the corn borer are commonly encountered in the collection of field data. These consist of *Masicera sevilla* Rond., a tachinid, and two hymenopterous, *Eulimneria crassifemur* Thom. and *Microbracon brevicornis* Wesm. Records show definitely the presence of all three species in southern Czechoslovakia, Hungary, and northern Yugoslavia. *Masicera sevilla* Rond. occurs in southern Yugoslavia, Rumania, and Baden, Germany, and *Microbracon brevicornis* Wesm. in southern Yugoslavia. The other hymenopteron, *E. crassifemur* Thom., has also been recorded from Rumania and Baden.

Besides these more important parasites, a species of Trichogramma commonly attacks the eggs of the corn borer in Hungary and northern Yugoslavia. *Dyctes paratoria* Roman parasitizes a very small percentage of the larvae occurring in these two regions, and a species of

Eulophus has been observed occasionally in southern Czechoslovakia. Another tachinid, *Exorista vulgaris* B. B., has been recorded from the Dalmatian coast of Yugoslavia.

The degree of parasitism by any one species, or by all of them, varies considerably in different localities and even in various fields of the same locality. Table 8 lists by region the average parasitism by the three chief species, and the maximum by locality observed in 1923 to 1927, inclusive.

TABLE 8.—*Parasitism of the European corn borer by its three principal parasites in the central European areas, as observed in 1923–1927*

SOUTHERN CZECHOSLOVAKIA

Year	Parasitism by—			Total parasitism
	[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average	[illegible]	[illegible]	[illegible]	[illegible]

HUNGARY

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average	[illegible]	[illegible]	[illegible]	[illegible]

NORTHERN YUGOSLAVIA

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Average	[illegible]	[illegible]	[illegible]	[illegible]

MAXIMUM PARASITISM IN ANY [illegible] TOWNSHIP

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maximum in the [illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible] [illegible] [illegible]

Since no intensive biological study has been made of these parasites as they exist in this region, some brief statements relative to their seasonal history are here presented, based upon field data and information already gathered by other workers.

Masicera sensitiva Rond., as in other regions of its occurrence, probably overwinters as a second-stage larva within the body of its host. Host pupation and emergence taking place in the early spring. The finding in 1926 of two live puparia of this parasite on August 21 and

of another on August 27 would indicate the possibility of at least a partial second generation in central Europe.

Eulimneria crassifemur Thom. normally has but one generation in central Europe. The parasite overwinters in the larval stage within its cocoon and emerges early in the following spring. As soon as corn-borer larvae of sufficient size make their appearance in the field the females begin depositing eggs within their bodies. Development of the parasite larvae within the body of its host appears to take place very slowly during the summer months, the spinning of cocoons not occurring until late in the fall.

It is W. R. Thompson's opinion that the detailed data at hand are indicative of the occurrence of a type rest period in the first-stage larvae.

Colonies of *Macrocentrus ancylivorus* Rohw. are found early in the spring in overwintered cornstalks, and during most of the summer in growing corn. The chief value of the field data on Microbracon lies in the demonstration of the continuous presence of this parasite throughout the developmental season of the borer.

It is a generally accepted opinion that the adults overwinter, although there is a possibility that the species also hibernates in the larval stage within spun-up cocoons.

The females are often abundant and deposit their eggs upon overwintered host larvae by the middle of April. At least two generations are completed before the elimination of the host by pupation. The parasites in their development pass directly from the overwintering host to the growing larvae of the summer season, and the generations so overlap that it is difficult to define their exact limits.

Macrocentrus ancylivorus is usually most plentiful in localities where it is a common practice to stack old stalks in large piles. As it is known that the parasite is most effective at a time when all such stalks should be out of the way, the practice lessens the possibility of making this species effective by artificial colonization.

Observations have been made upon the presence of egg parasites, but a really satisfactory survey is impossible, owing to the lack of time necessary for the proper handling of the host eggs collected in the field. In Hungary during the season of 1920 a total of 418 egg masses were collected from eight widely separated localities, and the presence of a species of Trichogramma was indicated in Gyor in the northwest, and Nagykaniza in the southwest, and 164 adults were bred from 20 host-egg clusters collected in Fors in the south-central portion of Hungary. In the Yugoslavian territory 203 clusters, comprising 5,953 eggs, were collected, from these 15 Trichogramma adults were bred, the material originating in the town of Stari Becej.

These observations were continued in 1927 in both Hungary and Yugoslavia. In 10 townships an average of more than 20 per cent of the eggs of *Pyrausta nubilalis* were destroyed by a species of Trichogramma, and 5 other townships showed an average parasitism of more than 30 per cent. With the exception of only 2 townships, this parasitism occurred in the center of the corn belt.

During the season of 1924 *Melittobia acasta* Wlk., a parasite of *Eulimneria crassifemur* Thom., was bred from material collected at Mezobegyes, in the southeastern section of Hungary. This is the only record of a hyperparasite obtained during the 4-year period of investigation.

Routine collection of field data on the parasites, in connection with the other phases of the project, is essential to the proper evaluation of this biological factor in the reduction of larval populations. It should be pointed out, however, that much field information exists regarding the distribution and intensity of parasitism by the chief species of parasites in the central European plains, but lack of space excludes it from this publication. The data referred to will be discussed in a paper particularly dealing with this subject.

DISEASE

Although thousands of corn-borer larvae have been observed in many localities during the four years of investigation, no widespread mortality that could be traced primarily to disease has been observed. It is the opinion of the writers that the reduction of numbers by disease in the natural control of the insect is of minor importance when compared with the operation of other factors.

Several observations on disease as a factor in control are among the field data, however, and illustrate the general condition. In August, 1925, an assistant made observations on a disease which killed an average of 20 per cent of the overwintering larvae in five fields in the vicinity of the town of Hunedoara in northern Yugoslavia. The following year from this cause a mortality of 50 per cent. This, however, is the only instance of prevalent disease of the corn borer observed in the work, and one ordinarily finds only an occasional larva killed by disease.

At Gherghita, in Rumania, the senior writer observed numerous dead overwintering larvae which were quite dry and covered with a fungus, but it is not known that disease was the actual cause of death.

OTHER NATURAL ENEMIES

No enemies of the corn borer other than those mentioned have been recorded in sufficient numbers to be classed as effective means of fighting the borer.

The junior writer, in the course of field observations in Velika Kikinda on June 13, 1926, observed numerous sparrows feeding upon the larvae and pupae of the corn borer in old cornstalks. Large flocks of these small birds are frequently observed flying about corn stacks, and undoubtedly numerous larvae are destroyed by them.

Doctor Jablonowski, in his manuscript heretofore cited,[3] records that Doctor Pako has seen the chimney swallow (*Hirundo rustica*) capture the adult of *Pyrausta nubilalis*, but the reduction of numbers in this manner is not important. The possibility is also recorded that the rook (*Corvus frugilegus*) accounts for the destruction of a certain number of the adults, and for some of the larvae remaining in the stubble and scattered remnants of corn upon the fields. There are undoubtedly other natural enemies of the insect, of more or less importance, but they are to be noted only by chance observation.

[3] JABLONOWSKI, J. Op. cit.

CONTROL

The history of control work against the corn borer in the central European plains is chiefly that of isolated attempts of large growers to combat the insect by burning the crop remnants or feeding them to stock. In all the area of fairly high infestation there is no real consistent program of repressive measures against the insect, although on the occasion of several bad outbreaks in the past the Government has issued edicts making obligatory the taking of precautionary measures. There are, however, unintentional checks upon the abundance of the insect, as is shown by the lighter infestation in certain regions where the culture is particularly clean and systematized, in marked contrast to the infestation in areas where the stalks are left to collect from year to year. The latter procedure, however, is sometimes necessitated, particularly in the center of the corn belt, by the lack of fuel and in cases where the old stalks are used as a substitute for straw or wood.

In 1897 Jablonowski recommended as a measure of control the burning of the stalks and crop débris. Again in 1908, after the outbreak of 1897, he issued a paper (41) giving a full account of the damage caused by the corn borer, recommending great effort to get rid of all unused portions of the corn plant before March of the following spring and pointing out the necessity of removing and burning both the stubble and the cobs. In 1916 the insect again became so serious that it attracted the attention of every agriculturist in the country, and consequently the Hungarian Government issued an edict on February 26, 1917, making it obligatory for each municipality to see that certain measures recommended were taken to control the pest. In brief, this edict carried the following provisions:

Cornstalks, cobs, and stubble were to be destroyed by being fed to stock, being used as silage or compost, or by being burned before April of the following year.

If, upon formal notice, the edict should not be observed, the work was to be done by the officials and the expense charged to the owner.

Fines and imprisonment were prescribed for omitted conduct, but these penalties did not preclude the necessity of carrying out the precautionary measures.

No data are available on the results obtained by this edict, nor as to how systematically it may have been enforced. However, the probable efficiency of such methods may be judged when one takes into account the fact that even to-day the farmers refuse to see the damage done by the corn borer, and usually ascribe it to an "act of God." The writers had an opportunity during the seasons of 1926 and 1927 to observe the effectiveness of such a measure, when the edict of 1917 was renewed at the beginning of 1926, on account of the increase of the insect in 1924 and 1925. Although the writers covered the entire country of Hungary in their travel in the course of these seasons, not a single instance of township-wide clean-up was noted. Up to the present time very little information has been gained concerning the real effectiveness of clean-up measures in reducing the intensity of infestation in the native home of the insect; and in order to formulate theories concerning the checks operating to control the pest field observations tending to show what natural factors are in operation must be relied upon. The important factors will next be

A.—Scene on the Hungarian plain near Mezöhegyes.
B.—Typical piles of old cornstalks at Mezöhegyes, large estates in the center of the corn belt.
C.—Family cornstalk reserve near Budapest.

A.—Old method of growing hops, with wooden pole

discussed, but it should clearly be realized that any evidence here offered as to the effectiveness of any natural factor is not by any means conclusive; the available data are too scanty, and the results of four seasons of investigation do not offer a foundation for the study of the large series of both supernormal and subnormal fluctuations that would be required as a basis for reliable conclusions.

AGRICULTURAL PRACTICE

CROP DISPOSAL

As previously stated, no widespread attempt at systematic clean-up of corn remnants, or at cultural practice to control the insect, was observed in the central European plains. In 1926 and 1927 this was also true, although the edict making obligatory the destruction of old stalks was revived and more rigidly enforced. The failure of this edict to control the insect in the large corn-growing areas may be largely explained by the fact that throughout this practically treeless region the dried stalks have an immense value as fuel and as a substitute for wood for farm use. Another cause of failure lay in the fact that no great effort was made to have the prescribed measures enforced. Many large growers are careful to keep their fields clean and to see that the crop remnants are disposed of before the following spring, but these cases are so isolated in any one region that any resulting reduction of the pest would be difficult to evaluate. Owing to the lack of positive information the data collected during the past seasons can be relied upon only to furnish indications of unknown value.

As one travels from the center of the corn-producing region under discussion, where are such heavily infested localities as Velika Kikinda, Veliki Bečkerek, and Senta, all in Yugoslavia, and Mezőhegyes, in southern Hungary (pl. 9, A, B, C), to the northwestern area of considerably lighter infestations near Győr, Kapuvár, Kisbárom, and Pápa in the northwestern part of Hungary, one is led to believe that one of the factors controlling the difference in larval population between the two areas is that of prevailing agricultural practice. In the southern area the nondisposal of remnants of the corn crops offers an excellent opportunity, year after year, for the insect to reestablish itself in considerable numbers. On the other hand, in the northwestern area clean culture and the disposal of corn débris are matters of farm routine, not primarily for the control of the insect but because the type of agriculture is more diversified and the farmer wants his land clean for the crop that is to follow. It has been the writers' experience every spring in which observations have been made in the area that old stalks were extremely difficult to find, particularly at the town of Pápa, where a whole day was often required to obtain material upon which to base a satisfactory life-history count. It must be remembered, however, that this area does not contain nearly so much land planted to corn as does the southern area, and this difference must be considered in describing the cause of the diminished infestations observed toward the northern limit of corn production in central Europe.

To emphasize the authors' opinion that organized clean-up of débris of the corn crop should be the main feature of the effort toward

control, the unquestioned success of the clean-up in 1927 in reducing larval population in Baden, Germany, is here mentioned.

Under the direction of Dr. W. Zwölfer, of the Baden Agricultural Chamber's Plant Breeding Experiment Station, Rastatt, Baden, the town of Baden and its environs were thoroughly cleaned up before the spring of 1927. Following the trend of 1925 and 1926, no increase in infestation would have been expected in 1927 in the Baden region. In that year warm nights during the oviposition period and warm, humid weather during the presence of the earlier instars were unusually favorable for larval development, and an increase in infestation throughout the province was indicated. A survey from August to September, comprising 19 townships distributed from the north to the south of Baden, revealed that Rastatt stood alone with a reduced larval population in comparison with that of 1926.

This reduction is all the more striking in view of the fact that in 1927 in the other localities of Baden there was an average of 700 per cent increase in infestation over that of 1926. The year 1927 was an exceptionally favorable year for the larval establishment, and Rastatt Township undoubtedly would have shown a corresponding result had not the control program effected a reduction of 86 per cent.

As pointed out, although the data are not sufficient as yet to determine the effect of clean-up work upon the annual establishment of the larvae in the various years, they do show the tremendous importance of a well-organized clean-up as an efficient repressive measure.

CONCENTRATION OF HOST PLANT

The regions in the central European plains which support heavy larval populations are generally those which have the greatest percentage of land devoted to the culture of corn, and hence, as a concomitant, have large quantities of crop débris.

Concentration of the host plant only, however, does not necessarily indicate an area of heavy infestation, nor is the reverse true in all cases. An illustration of this fact is shown by the conditions present in the Wallachian Steppe of Rumania, where, notwithstanding the heavy concentration of corn and the large quantities of crop débris, the corn borer is not an economic factor. In this case climate seems to be the limiting factor.

Another striking case of unlimited host material but low larval population, due in this instance to a change of agricultural practice, is found in the hop-growing districts of Bohemia in northwestern Czechoslovakia. In the course of many conversations with experienced hop growers the writers found it to be the general opinion that the gradual change from the old method of cultivation, with the use of wooden poles, to the later method, in which wire supports are utilized, had much to do with the elimination of the insect as an economic factor. There has not been an unusual appearance of the insect in those districts for the last 20 years. During the interval from 1828 to 1890, inclusive, the corn borer was considered the most serious enemy of the hop plant. After that time the system of wire supports for the vines came into use throughout the area. (Pl. 10.)

With this change of system the clean-up after harvest became more thorough, as the vines could be very easily stripped from the wires,

carried to a convenient spot, and burned before the next spring. To a certain extent, also, this method did away with available places for the hibernation of the larvae, which formerly migrated from the stalks to the crowns in the wooden poles previously used for supports. Probably a third factor in the elimination of the pest was the more general use of commercial fertilizers, which followed the introduction of the supporting wires, and which many growers believe are instrumental in killing the stray larvae that might overwinter in crevices in the soil at the base of the vine and in destroying those remaining in the stubble, which is from 2 to 3 inches high.

The conditions in this region also hold true for the more southerly areas of hop culture such as are found in the vicinity of Mohács, Hungary, where, in 1925, a large area of hop culture was inspected and no infestation was found.

Concentration of a favored host plant no doubt plays its part in the production of various intensities of infestation by the corn borer, but to express the value of this factor in quantitative terms is at present impossible. Such concentration, coupled with an increase in sheltering debris, is an important factor in causing correspondingly higher larval population in certain environments. This fact is illustrated by the steady increase in numbers of the borer in the State of Baden, in Germany. Grain corn in this region was practically unknown commercially or agriculturally before 1920. From that year until 1922 there was a rapid increase in the number of acres devoted to corn growing, and in 1922 the corn borer was first noted as a pest. The areas planted to corn continued to be augmented, and the borer population steadily followed, in 1926 the borer caused the prognostications of a future menace to the crop. This increase continued the next year, and in 1927 the most striking widespread advance occurred in all localities in Baden with one exception, Rastatt, in the vicinity of which an organized clean-up campaign was carried on.

This discussion illustrates both the need to analyze carefully each environmental factor, in order to establish commercial "danger points," and the need to ascertain for each environment the possibility of larval concentration.

CHANGE OF HOST PLANT

As the substitution of various varieties of sorghums for corn as fodder seems to be economically practical in some of the North American corn-producing centers, a study of the possibility that such plants may be injured by the corn borer was begun in Hungary in 1927. Five varieties of common grain sorghum and two varieties of sorgo were planted in each of five localities, representing typical differences in agriculture in the central European plains. The only infestation found was in plats located at Gyór, in northwestern Hungary (fig. 8, p. 40.) Of 701 plants of dwarf broomcorn 2, or 0.29 per cent, of 388 plants of reed kafir 2, or 0.52 per cent, and of 342 plants of dwarf yellow milo 2, or 0.58 per cent, were infested. Although an extremely low infestation was found in the sorghums under observation, the probability that sorghums might continuously support a low but significant larval population in this particular type of environment should prevent the making of the general assumption that sorghums are practically immune from attack by the corn borer. A careful

study of the environment in which sorghums may be used as a substitute for corn must be made, as is shown by the fact, established in Guam and in the experimental plantings in eastern Massachusetts (3), that certain varieties of sorghum may sustain heavy larval populations.

TYPES AND VARIETIES OF CORN

TYPES

When this project was started in 1924 there was current a belief that dent corn would never be as heavily infested as flint corn or suffer a comparable degree of commercial loss, but in the light of further data upon infestations in the North American areas the belief has been found erroneous. The information obtained in the central European plains also definitely shows that dent corn is severely injured by the corn borer; in fact, the corn-belt center of Hungary and Yugoslavia, where the greatest losses have occurred, is a typically dent-corn region.

As to which type of corn grown in the same area stands the best chance of being the more heavily infested there does not seem to be a striking difference between the dent and flint types. The discovery of any such difference, if indeed it exists, is made difficult by the fact that in the southern areas very little flint corn is grown, this type being chiefly confined to the more northern districts, where dent corn is seldom planted. It was also observed that when flint corn was grown in the south it was usually of the "100-day" type, planted very early, and so rendered liable to a heavier infestation.

At the present time it would be hazardous to draw a definite conclusion as to which type of corn is likely to be the more heavily infested, although the data now collected show that during three years of observation the flint varieties have not generally been infested as heavily as the dent varieties. This question is intimately involved with the predominance of a certain type in a particular region and the attractiveness of the two types, because of vegetative conditions, at the time of oviposition.

It is the writers' opinion that in the large centers of corn culture there is not much difference between the infestation in the two types, although data taken in 1926, in the southern section of the corn belt, show that the dent corns sustained three times as much larval population as did the flint corns. It is known that during the spring in this region the flints were not so far advanced as were the dents, and that the data were almost exclusively taken from the large white and yellow Hungarian flints. That this point must be taken into consideration is indicated by the infestation in the corn-belt center during the season of 1924, at that time the flint varieties were much more heavily infested than the dent varieties. The chief point of interest to be emphasized, however, is that the type of corn which predominates in any region carries the bulk of the infestation, and the predominance of the dent over the flint type decreases from south to north.

VARIETAL DIFFERENCE

It is a common experience throughout Hungary, in questioning farmers in regard to the varieties that are most susceptible to the attack of the corn borer, to obtain in many cases the response that Padua White, belonging to the flint type, has been so badly infested

by the name that its continued planting has become questionable. This corn is probably a cross between the native Hungarian types and corn which was originally imported from the region surrounding Padua, in Italy. The plant produces a good grade of ear, with 10 to 12 rows of large, soft, white kernels, and is commonly designated as a "floury" corn. The planting of this variety throughout Hungary has practically ceased, presumably owing to the attack of the insect.

In the course of field observations made by Mr. Malatea, an assistant in Yugoslavia in 1925, it was found that Mastodon White, a dent, was much less infested than other varieties of corn in the same locality. A planting of this corn at Subotica, seeded on April 6, was found to have no infestation during the early part of the season, when the stalk infestation of the other varieties in the same district averaged 12.5 per cent. This region was revisited at harvest time, and the data taken then show a stalk infestation in the Mastodon to be only 33.7 per cent, while similar infestation of other varieties averaged 80.9 per cent. At this time the larval population in Mastodon was 42 per 100 plants, and the average for the township was 330. Investigations during the following season showed, however, that there was no apparent difference in infestation between this variety of corn and others grown in this region.

In the course of these observations other cases were thought to indicate a variety less susceptible than usual to attack by the corn borer. In all cases, however, the differences in infestation were evidently not consistent, and their explanation must be found in the operation of some other natural factor.

In 1926 the Department of Agriculture of Czechoslovakia undertook an investigation to determine what varieties of American corn could be adapted to the corn regions of that country and to estimate the possibility of damage to them by the corn borer. A large number of both dent and flint varieties are now grown on the fields of the various experiment stations, and detailed data for two years regarding their infestation by the borer are available. Some of the more important data for four varieties, grown both at Kumarno, in Poland (not the Komarno in Czechoslovakia, shown in Figure 1), and at Beregsas, in the eastern part of Czechoslovakia, are presented in Table 9. These data are averages for the two localities and for the years 1926 and 1927. Data for only two years are not sufficient in such a case as this to warrant definite conclusions.

TABLE 9.—*Average data for 1926 and 1927 on the infestation by the corn borer of four varieties of American corn, grown at Kumarno, Poland, and at Beregsas, Czechoslovakia*

Variety	Infestation of plants	Infestation of ears	Larvae per 100 plants
	Per cent	Per cent	Number
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

Judging from their experience in the area infested by the corn borer in the central European plains, it is the opinion of the writers that the variety of corn has, in comparison with the more important factor of the time of planting, little to do with the possibility of sustaining damage by this insect. Experiments now being carried on in Europe and in North America, however, may bring to light varieties with different degrees of susceptibility.

TIME OF PLANTING

Everywhere in the corn-growing area of the central European plains the farmers emphasize the fact that corn planted very early in the spring is much more heavily infested than the later plantings. Some illustrations of this fact are to be found in data presented in Table 10, on the infestation of corn, planted at successive dates and in widely separated localities. Because of the diversity of the observations the data for all localities and varieties, and covering the four years 1924 to 1927, inclusive, have been averaged together. Except for the latest planting, May 27 to June 2, the progressive decrease of infestation with successive dates of planting is very marked.

TABLE 10.—*Average data on the infestation of corn planted at successive dates at widely separated localities in the central European plains, 1924–1927*

Time of planting	Fields	Infested plants	Infestation	Average number borers per infested plant
	Number	Per cent	Per cent	Number
March 25 to 31	2	85	20.1	1.62
April 1 to 7	27	68	20.1	1.63
April 8 to 14	111	46	20	1.63
April 15 to 21	155	31	11	1.67
April 22 to 28	146	21	7	1.64
April 29 to May 5	72	13	3	1.63
May 6 to 12	36	8	2	1.63
May 13 to 19	25	6	1	1.63
May 20 to 26	5	3	1	1.63
May 27 to June 2	3	20.5	13.1	162
Total	583			

At present no attempt will be made to draw definite conclusions as to the correlation between the various dates of planting and the weather conditions prevalent during each season, since a series of records covering at least 10 years should support such deductions. The data show, however, that corn planted in the period from March 25 to April 14 sustains the heaviest infestation, and corn planted in the period from April 22 to April 26 shows it to a lesser degree. In all years many of the fields planted at earlier dates show in the detailed figures a lesser infestation, probably owing to the fact that germination was so delayed that after the interval from May 15 to May 30 the corn was really not in as good a condition for growth as was that planted between April 1 and April 14.

The figures indicate a sharp decrease in the probability of infestation in corn planted after May 13. This date, however, even for the center of the corn belt, is much too late for such large dent varieties as Fleischmann, Bánkuti, and Ruma Golden to mature properly. April 22, however, is not too late to plant these varieties, and planting

at this date might enable the grower to escape an appreciable amount of damage.

Although the data at hand are incomplete, they indicate the possibility of breeding a variety of dent corn, yielding well and suited to the requirements of the central European plains, that might escape considerable injury if planted after April 25. It must be kept in mind, however, that in that type of moreland with its corresponding climate, the spreading out early in the season of pupation and emergence would preclude the possibility of developing any variety which would entirely escape serious damage in a bad year. At best this would be only one phase of the necessary control.

ENVIRONMENTAL FACTORS IN CONTROL

SOIL

After the status of the insect in 1924 had been ascertained it was found that the heaviest larval populations almost invariably occurred in corn grown upon river alluvium or loess-loam soil. In the immense area of sand, soda soil, and loam which lies between the Danube and the Theiss Rivers in Hungary, where corn is grown to a small extent, no infestation was found in that year, and, according to all reports obtainable, the insect had never been abundant there. Upon the combination of gravel and loam soil found in the vicinity of Szombathely, also, corn has been very lightly infested during the past four years. There is another factor, however, which may have more weight in determining the possibility of infestation by the insect in any given region—the concentration of corn, with the consequent crop débris.

That there might be some indirect relation between the soil type and infestation was pointed out as early as 1924 in a "report of work" submitted by the senior writer. At that time the advisability of planning the field work so as to study this feature was carefully discussed, and it was decided that the results would not be of enough importance to warrant the additional labor imposed upon the collection of field data. The amount of crop débris remaining, the effect of dates of planting, and the climatic limitations in various localities appeared to be important factors quite overbalancing the possible effect of soil type, except perhaps for infrequent cases which would not be evident from casual observation.

In 1927, at the suggestion of E. N. Transeau, of Ohio State University, who has collaborated with the Bureau of Entomology in its ecological investigations in Europe and North America, the fields from which systematic data were taken were carefully located upon a soil map. The results of a grouping of these fields as to soil type are shown in Table 11. The separation of the data by zones and soil types into groups follows the system employed by Peter Treitz, the Royal Hungarian geologist, in mapping the lands in old Hungary.

TABLE 11.—Average infestation by larvae of the *European corn borer* in 1927, in fields in *Hennepin* and *Fayette* Counties, classified by climatic area and type of soil

Type of soil	Region 1, brown		Region 2, dark		Region 3, dark-brown		All regions
	Fields	Average per 100 plants	Fields	Average per 100 plants	Fields	Average per 100 plants	Average per 100 plants
	Number	Number	Number	Number	Number	Number	Number
Loess	4	68	36	77	96	103	83
Marl	11	51	3	72	3	4	51
Peat		30	3	64	3	4	32
Alluvial soils	1	29	10	68	3	141	74
Ferruginous gravel	6	33					33
Limestone			1	35		3	3
Alkali soils			1	105	3	3	54
Meadow clay					3	3	3
Loess soils					3	109	109
All soils	22	41	54	74	109	108	80

It should be pointed out that when conclusions were drawn from the field data and the type of soil was taken into account, a certain discrepancy entered into the assignment of a field to a particular soil type. All fields were first located upon a very detailed map of the county or township, whereas the only soil map available was drawn to a scale only one-fifth as large, thus in many cases wiping out small local variations in soil. In order to avoid as many errors as possible in the original data it would be advisable to take samples of soil from each field selected, but this procedure would be impractical, owing to the time required for other observations.

The 265 fields furnishing the data for Table 11 were first arranged according to planting dates for each type of soil. There was enough variety in these detailed data to prove the necessity of taking the date of planting into consideration if the field data were to be used as a basis for determining the expectancy of commercial loss for a particular type of climate in connection with a certain kind of soil. In analyzing the 85 fields upon loess soil in region 1 the insufficiency of the data was evident, since a fairly accurate table would not be constructed competent to bring out the average differences within a certain year which were due to the time of planting.

In the consideration of all areas, because of the insufficiency of data the soil types "meadow clay" and "peat" head the list of soil types tending to favor higher larval populations. In region 3, in which these fields occur, 26 fields were found on loess soil in which the population was considerably above that shown for these two types of soil. The sufficiency of these averages to warrant comparison must be derived from comparable detailed data. In general, however, it is true, and the data support the statement, that soils of the loess, alluvial, and mixed alkali types support heavier larval populations than the other types.

The data show that there is a difference in larval population between the regions or classes named in Table 11, but the use of these classes as the index to "possibility of damage" for a particular locality is not warranted by them, since the classes themselves are too broad in limit to bring out the economic effects of

such important factors as the concentration of the host plant, the amount of debris remaining, and the general agricultural practices. All of these factors occur in particular temperature-moisture combinations which directly affect the corn borer. For instance, the fact that in the central European plains the prairie climate supports the highest larval populations does not imply that this class of climate is a useful index, except in so far as the concentration of host, the agricultural practices, and the insect's temperature-moisture requirements are the same for all regions considered. The basis for analyzing a locality as to the expectancy of damage is further discussed on pages 45 to 51.

CLIMATIC FACTORS

Since the first year's work upon the problem of control of the corn borer the fact has been appreciated that certain peculiarities in the insect's development must be thoroughly understood before the adoption of particular cultural methods of control in the various regions into which it has spread. The development of distinct habits concomitant with a certain number of generations annually, the comparative stability of the seasonal rhythm in certain environments, and the insect's inherent ability to adapt itself to widely different environmental conditions, even within the same zone of seasonal history, have made necessary a thorough analysis of these peculiarities of development. The results of such an analysis may serve as a basis for determining what precautionary measures should be taken to prevent the rapid spread of the insect and the line of attack to be taken in its control after it has become established in certain environments. A thorough discussion of these problems and of the research on them that has already been completed will be found in two papers recently published by the senior writer (1, 2).

It was hoped that by these investigations, besides the immediate usefulness of the data collected from the native home of the insect, a basic knowledge of the ecology of the insect would be gained that would aid in correctly planning a practicable control program, particularly for the period after the establishment of the insect in the Corn Belt of the United States had been completed. During the four years of investigation the data have therefore been collected in accordance with a plan that would eventually lead to the analysis of important environments in terms of the fluctuations of the insect as a pest. Such a short time has been devoted to the collection of these data that no definite conclusions can be drawn; moreover, such conclusions should not be attempted without a minimum of 10 years' detailed data as a background. There are, however, a few outstanding facts which, although too inadequate to warrant definite application to the insect's fluctuations, are valuable in pointing out the correlation of field data with a working hypothesis and experimental evidence.

The particular phase of the control work which could be materially aided by ecological information is that in which consideration must be given to the extent and frequency of the repressive measures found necessary in different areas. If the administration of control funds might be aided by knowledge which had the effect of roughly classifying areas of established infestation and pointing out the regions where infestation would possibly be frequent, an appreciable

saving would result. The ideal plan would be to define each area by its possibilities, and allot control funds accordingly. To depend solely upon this ideal would, of course, be foolhardy. However, all ecological information leading to the general understanding of the causes responsible for the rise and fall of the corn borer in various areas, and of the possibility that the insect in such areas will rise above the concentration conceded as necessary to inflict commercial damage, would increase the chance of success in the planning and disposition of funds connected with any logically founded program of control.

It is not to be expected that a definite value can be ascribed to any particular environmental fluctuation as indicating the exact result which may or may not be produced, but it is hoped that the causes of outstanding fluctuations may be explained. The practical ecological problem resolves itself into two main features: (1) The definition of the limits of the different seasonal-history areas, and (2), the study of the causes of *different* intensities of infestation.

The store of data upon the first phase of this project has been considerably enlarged during the past 4-year period, and a detailed discussion of this matter is reserved for a future paper. It may be stated, however, that these additional data follow the trend of the data and the hypotheses advanced in the senior writer's previous papers (*1*, *2*).

Of immediate economic significance are factors causing varied degrees of concentration in different localities, factors causing the rise and fall of particular concentrations, and the possibility of occurrence of combinations of such factors. Of particular importance are data explaining "outbreaks" or "reductions." Table 12 presents a number of cases illustrative of types of conditions of temperature and moisture existing when certain results were apparently produced. Correlation between Tables 7 and 12 will also illustrate the economic value of such ecological information. It must be remembered that conclusions drawn from these insufficient data are most certainly not to be taken as final criteria, but are offered only as an indication of expectations.

Table 12 presents the deviations from normal temperature and normal precipitation which characterize separate portions of 11 years there designated and the corresponding relative change in the population of the corn borers and in the intensity of infestation. It is believed that these changes result from the climatic conditions presented in the table, and therefore they are tabulated under "Influence of year." Similar results, for which it is not practicable to supply the antecedent deviations, are given for the years 1894, 1896, 1918, and 1919 to 1921, inclusive. Of each pair of climatic data for a given interval and year the upper denotes deviation of temperature, in degrees Fahrenheit, and the lower deviation of precipitation, in inches, from the normals established by observation for many years. For the years 1891, 1892, 1897, 1916, 1924, 1925, and 1926, the population and infestation in general increased; the climatic conditions for 1893, 1898, and 1917 allowed the establishment of previous increase, but stopped further increase; and the conditions for 1926-27 resulted in extreme reduction. The data for 1878-79 were collected in the vicinity of Odessa, in Russia, some-

what to the eastward of the region otherwise considered here, to which the subsequent data relate.

TABLE 12.—*Deviations from normal temperature and precipitation for portions of selected years, compiled from data collected in the central European plains and arranged for comparison, with the attendant relative degree of infestation by the European corn borer*

[Two types of records, relating to egg-mass counts and corn-borer larvae, discuss the relation of temperature to infestation and the same temperature conditions, but differ from a previous compilation by approximately 100 degrees Fahrenheit. The footnotes to the original figures (1 and 2) are reproduced in full in the quarterly summaries. Precipitation is given inches, which (multiplying by 2.54) equals centimeters. Unusually warm, dry, and unusually cold, wet periods are shown in the body of the table according to these criteria]

Year	Deviation of temperature from normal	Deviation of precipitation from normal	Critical period	Apparent effect on Moths	Effect on Larvae	Overwintering loss	Difference of loss, compared to—	
							Effect on Larvae	Intensity of infestation
1915–1916								
1916–1917								
1917–1918								
1918–1919								
1919–1920								
1920								
1921								
1922–1923								
1923–1924								
1924–1925								
1925–1926								
1926–1927								
1927								
1928–1929								
1929–1930								
1930–1931								
1931–1932								
1932–1933								
1933–1934								
1934–1935								
1935–1936								
1936–1937								

[1] The data for 1926 do not appear to belong in this series of tables. In the east much of the region submerged with the rest of the table, and the other data are to the normal throughout [illegible].
[2] Conditions favorable to the corn borer.
[3] Conditions unfavorable to the corn borer.
[4] End of the period of increase, and a condition favoring reduction.

In order that the reader may appreciate the type of season which causes an outbreak or reduces the intensity of infestation, the data in Table 12 will be discussed from the standpoint of a hypothetical year of outbreak, or a series of such years, and an attempt will be made to bring out the type of fluctuation in temperature and moisture which, taking place in a particular period, indicates a condition potentially favorable to an increase of infestation. It should be pointed out that this discussion is not intended to imply that any one type of fluctuation in a particular period can itself produce such an increase, but that, with certain factors present in certain other periods, that type of fluctuation is an essential antecedent of the possible outbreak. In Table 12 "normal" means the intensity of infestation normally expected to occur in this particular environ-

ment, and "increase" and "reduction" refer to numbers of corn-borer larvae present, and do not indicate a relative degree of commercial loss.

The judgments of the various years are expressive of the attention which would be attracted to the presence of the insect. For instance, if one were in the center of the European corn belt one would normally expect a loss of 15 per cent of the corn crop, the insect population being at its average level, while practically no loss would be expected under similar conditions were one near the limit of the region of corn production. An outbreak of the corn borer in each locality would be noticeable, but judged from a different standpoint.

In studying the abnormal cases presented in Table 12 the season should be kept in mind, and no attempt should be made to evaluate the fluctuations in various periods in terms of their relative weight in producing either increase or decrease.

According to previous knowledge of the corn borer in North America and Europe, gained both from the laboratory and from the field, the hypothetical season for increase in a one-generation region as represented by the environment found in the central European plains, should begin with September. In this month warm-dry conditions must prevail to hasten the development of the stragglers; i. e., the larvae in the third or fourth instar which must mature before entering the true rest period. Such conditions are required for potential increase, since more individuals enter the winter than if these stragglers are killed by lack of the temperatures needed for development.

To favor increase of borers during the following season, the period of hibernation in this particular type of environment would need to be warmer, or distinctly wetter, than normal. In a "cold-dry" environment a decrease in temperature is not to be considered as producing a condition unfavorable for hibernation, since conditions favorable for hibernation are found in environments where the total of temperature means for this period is 44° F. lower than the standard total for the corn belt. Only increase in temperature, therefore, is considered a positive stimulus to potential increase of borers. On the other hand, either increase or decrease in available contact moisture must be considered as producing positive and negative stimuli, respectively.

How these factors actually operate in tending to increase the numbers of borers is not at present known, but by experiment and by observation in the field it has been demonstrated that this type of fluctuation strongly favors both a hastening of the passing of the physiological rest period and an increase in the number of individuals ready to proceed with development at an early date in the spring.

The spring months should supply additional contact moisture after the normal "cold-dry" environment during hibernation, and this requirement is satisfied by the "spring-rain" type of climate which is normal in the central European plains. It follows that the increase is furthered by supernormal spring moisture before pupation, together with an increase in temperature to hasten development; or, if sufficient moisture has been made available throughout the hibernation period, particularly during the months of January, February, and March, the continuance of favorable conditions of contact moisture may to a certain degree compensate a fall in temperature.

The divisions of the season as indicated were selected to bring out those periods of the insect's life during which certain conditions are believed to be of great importance in causing fluctuations either mechanically or through their effect upon the physiology of the insect. As the data accumulate, these periods will have to be changed. At present the "summer" period hides several of the very important known factors which, occurring in June, directly increase or decrease the larval concentration; i. e., low temperatures and heavy rains, either or both occurring during oviposition, heavy rains at the time of the hatching of the eggs, and hot, dry weather during the presence of the earlier instars. All these conditions reduce considerably the number of individuals which can establish themselves.

It must be remembered also that means of temperature and moisture for such long periods as are presented in Table 19 do not permit accurate estimates of the value of conditions which have prevailed during a particular period. The statements in the analysis to follow must always be taken with this thought in mind, as the writers do not wish to overemphasize the importance of this type of correlation and produce a hard-and-fast picture of the insect season, but rather to develop indications of outstanding events which will lead ultimately to closer analysis. However, the purpose of this bulletin will be served by using the data as presented.

In Table 12 the beginning and the end of each period of increase has been indicated, and the series of years will be discussed with reference to these points.

It must be remembered that in judging whether any combination of climatic factors is favorable or unfavorable to the corn borer, the judgment must be translated in terms of the effect of such factors upon the percentage of establishment; that is, it must be determined whether the climate happened to be of a type in which only replacement occurred, one in which only a certain percentage of the probable annual establishment occurred, or one in which the factors unfavorable to the insect were of such intensity that a reduction of the replacement potentiality occurred. To clarify the matter further, suppose that a series of favorable years which have allowed the larval population to rise above the normal are followed by a year in which the climate actually decreases the annual establishment to a point even below the replacement value. Directly after this year, which climatically may be judged as an unfavorable, or "reducing," year, the larval population may still remain above the point which precludes commercial damage. Superficially, therefore, the year might be termed a favorable one when judged solely from the status of the insect.

The reader should not attempt to glean from these data, as presented, a judgment of the effect of the favorable conditions in one period as compensating for adverse conditions in another. Although the writers wish to point out for each period what they judge to be conditions favorable for potential increase of the larvae, they are unable to commit themselves as to actual quantitative compensating requirements. They have, however, indicated possibilities by referring, at certain points in Table 12, to footnotes indicating conditions favorable or unfavorable to the corn borer.

The favorable conditions culminating in the outbreak of 1892 are interesting as illustrating the effect of abundant contact moisture during the hibernation period of 1890-91, followed by a warm spring and a warm, dry September. The hibernation period of 1891-92 illustrates the effect of increase of temperature followed by an entirely favorable season, culminating again in a September in which the weather favored the entry into the winter of 1892-93 of a more than normal number of larvae. During this winter, however, the conditions were distinctly unfavorable, and a marked reduction resulted in the spring, summer, and September of 1893. The weather at that time was severe enough to bring the insect to the usual level by the season of 1894.

The conditions preceding the outbreak of 1898 were similar to those which characterized the winter of 1891-92. The record for the spring of 1897 bears evidence of abundant contact moisture, and both the summer and the month of September met the requirements considered favorable for increased numbers of borers. Further potential increase was again stopped by conditions prevailing during the hibernation period of 1897-98, similar to those that had effected an adverse result in 1892-93, although the lack of contact moisture during the earlier period was more marked in character. An interesting feature of 1898, when the larvae were reduced in number, was that the distinctly favorable conditions of spring were not in themselves powerful enough to offset the adverse conditions which preceded them and those that followed during the summer and September of that year.

The importance of a warm and wet hibernation period in producing increase of borers in a normally cold and dry hibernation environment is illustrated by the conditions of 1915 and 1916, the outbreak of 1916 and 1917 being exceptional in its degree of intensity.

This series is particularly valuable as illustrating the outstanding effect of having both factors during the hibernation period favorable for increase; i. e., warmer and wetter. This condition has been shown experimentally to be a tremendous stimulus to the insect. It is all the more striking in this case, when the seasons following these favorable hibernation conditions were not strikingly favorable.

An interesting series of years, 1924-1927, in which the insect rose to a peak in 1926 and dropped back abruptly in 1927, illustrates the points already discussed. This series of years is particularly interesting owing to the marked reduction of the insect population that occurred in 1927, thus not only completely stopping the increase but actually reducing the percentage of establishment considerably below the replacement value. This series also points out a fact previously discussed on page 48, that the continuance of "warm-dry" conditions during hibernation, although promoting increase in the number of borers in the next generation, tends at the same time to decrease ultimately the vitality of succeeding generations.

A glance at the period of increase extending from the hibernation period of 1923-24 to the end of the hibernation period of 1926-27 would lead one to expect a serious outbreak in the season of 1927. The fact that such an outbreak failed to materialize is an important point in obtaining a proper conception of the factors which hold the insect completely in check and materially reduce its numbers.

The temperature means for the spring of 1927 reveal both subnormal temperature and precipitation, a combination found in years of reduction, but their intensity is not revealed until their critical periods are examined. During April, 1927, the precipitation—subnormal, as just stated—was poorly distributed, and 50 per cent of it fell on two days, widely separated, and 60 per cent of the (subnormal) precipitation for May fell on three days. Besides these unfavorable conditions, April had 20 days below normal in temperature. Conditions tending to favor pupation began April 20 and continued for about 12 days, or until May 10. Then came a sharp drop in temperature to an average of 6° F. below normal, which continued for six days, or within four days of the time when the first pupæ is normally expected. During the remainder of May 10 days averaged 3.5° below normal for the first portion of the pupation period, and these subnormal temperatures are reflected in the slow advance of pupation on which data have been collected. The second adverse period of extreme importance occurred in the latter part of June, when the maximum oviposition should normally occur. This period was consistently below normal in temperature, and the minimum temperatures from June 20 to June 30 were all below 60°, the point considered favorable for deposition of eggs in normal numbers. As a further interference with establishment of the young larvæ in the field, three heavy rainstorms occurred on June 27, July 13, and July 17, respectively.

These adverse conditions, however, were not the last blow which the season inflicted upon the insect. In July drought conditions followed, of sufficient intensity to hasten the maturity of corn, markedly reduce its height, and seriously lower the expected yield; and, finally, September, which included a long abnormally cool, rainy period, probably played its part in reducing the number of larvæ that went into the winter of 1927–28. The adverse effect of this season is further brought out when it is considered that surveys from October 1 to October 15 showed a reduction of 88.8 per cent in the numbers of the larvæ in the central corn belt of Europe, as compared with the larval population of the previous year.

To point out still further the necessity for such an ecological understanding of a locality that the planning of a control program may be more logical in concept, the case of the Wallachian Steppes in Rumania is presented. Immense quantities of corn are grown throughout this large region, and no cultural reason is evident why the corn borer should not be as abundant there as in the central European plains. An explanation of this condition may lie in the fact that during 1924 and 1925 severe droughts appeared which prevented the maturing of a large quantity of the corn and killed many of the larvæ. Such droughts are typical of this region and are of fairly frequent occurrence. In contrast to these conditions, a fairly heavy infestation was present during 1926 in the hilly country surrounding Cluj, Rumania, a region also belonging to the steppes but where droughts are less frequent.

This discussion has presented merely the first steps in the analysis of the climate of any season, which are temperature-moisture combinations and their effect upon the larval population. The data are being collected in detail to provide a basis for expressing in general how favorable or how unfavorable a season may be to the insect

in terms of the percentage of establishment. When a temperature-moisture index can be obtained which takes into account the effects of possible combinations, the analysis of a locality should, of course, be weighed further by the effect of various other important factors previously discussed.

The limiting of this first general index must be narrow enough in scope and must take into consideration such meteorological details as to allow for an appreciation of all combinations of other factors influencing high larval populations.

The classes of climate and soil shown in Table 11, for instance, are too broad in environmental limits to be satisfactorily used as the basic index for distinguishing between localities in terms of expectancy of damage. The environmental limits within which crops may be damaged by the corn borer extend beyond the limits of corn growing, and the centers of corn production do not always correspond with centers of high larval population. The definition of a value, in order to express the chance of damage in a particular locality, should be based upon the type of temperature-moisture condition prevalent. The selection of these classes, however, must eventually be based upon combinations which are known to influence the insect's life directly and are expressed in terms of themselves, rather than upon a criterion which is ecologically an expression of the environmental limits of another life form.

The detailed data required to limit further the environment as above expressed would therefore need to show the type of soil, concentration of host plant, quantity of crop debris present, and prevailing agricultural practice, all of which are known to exhibit their effects within the temperature-moisture class in which falls the locality to be analyzed.

It should be pointed out that during the four years of the present investigation an immense amount of detailed information has been collected to the end of better evaluating, in terms of the effect upon the potentiality of damage, the factors just mentioned, and that at least 10 years' data from such a careful routine are needed to limit properly variations which may occur in any of these important factors and offer helpful and practical guides in the control of the insect in "danger" localities. The variations in these main factors and their effect upon larval population will be discussed when sufficient data become available. It is not expected that absolute specific values in terms of expectancy can be assigned to any series of combinations of factors; but there may result a useful basis for defining certain localities as to their "nearness" to environments in which the normal climate is such as to tend to the production of commercial loss.

Data collected to support the distribution shown in Table 7 will be used to analyze further any particular locality as to the possibility of its producing a dangerous larval population, and to ascertain roughly how far in each region the percentage of establishment needs to be lowered to keep the larval population below the danger point.

If such data are collected for a reasonable length of time it is evident that some aid will be available in plotting out points of danger, where extreme repressive measures must be taken year after year to effect economic control, as well as other points in which this demand will not be so imperative.

CONCLUSIONS

The data collected during the course of four years of investigation of the corn borer in central Europe, from 1924 to 1927, inclusive, lead to the following conclusions.

The variations in seasonal development and intensity of infestation by the European corn borer are attributable to fluctuations of factors in the environment.

The seasonal rhythm of the corn borer is to a certain extent persistent and is due to the formation of a physiological condition which forces the insect to develop a certain type of seasonal cycle. This physiological condition is formed by continued impress of a particular type of normal environment and persists after the impress of the environment is removed.

There are apparently no climatic or cultural reasons why the distribution of the European corn borer should not extend to all points in the main corn-growing regions of the United States.

Severe damage to corn, which has been observed in a typical corn-producing region quite comparable to the Corn Belt of the United States, and in which the corn borer is still increasing, points to the possible menace of this insect to our chief corn-producing centers.

The practice of clean culture, following a program which includes all possible means of reducing the borer population, is an essential feature of control. In general, the areas of comparatively clean culture suffer less from the ravages of the borer than do the regions where clean-up practices are not followed.

In one-generation areas heavy infestations may occur in crops other than corn, and in weeds as well.

The widespread distribution and local effectiveness of certain species of parasites of the corn borer occasion hope that parasites may be effective in aiding the program of control in North America.

All types of corn may be severely damaged by the corn borer. No variety or type was observed which was practically immune to the attack of the insect.

Severe losses in yield, occasioned by indirect injury, may occur in typical corn-growing centers. Such damage was particularly noticeable upon the plains of Hungary and Yugoslavia, where high winds, similar to those in the Corn Belt of the United States, occur in the latter part of summer.

The elimination of very susceptible varieties of corn and a proper regard for the most favorable date of planting appear to be two of the promising possibilities for control.

Radical changes in cultural practice are possible and may be effective in the control of the corn borer, as is strikingly shown by the fact that owing to a change in the method of growing hops in the center of hop culture in Europe the insect has ceased to be an economic factor in the production of this crop.

The classification of localities according to expectancy of damage may come to be of assistance in allotting the funds necessary for control of the borer, or at least for keeping larval populations from inflicting commercial loss. This classification must, however, be detailed enough to give proper weight to local differences. At present the available data do not warrant such a classification, and any efforts in this direction would be hazardous.

LITERATURE CITED

(1) BABCOCK, K. W.
1927. THE EUROPEAN CORN BORER, PYRAUSTA NUBILALIS HÜBN.: I. DISCUSSION OF ITS DORMANT PERIOD. Ecology 8: 45–59.

(2) ———
1927. THE EUROPEAN CORN BORER, PYRAUSTA NUBILALIS HÜBN.: II. A DISCUSSION OF ITS SEASONAL HISTORY IN RELATION TO VARIOUS CLIMATES. Ecology 8: 177–193.

(3) CAFFREY, D. J., and WORTHLEY, L. H.
1927. A PROGRESS REPORT ON THE INVESTIGATIONS OF THE EUROPEAN CORN BORER. U. S. Dept. Agr. Bul. 1476, 155 p., illus.

(4) JABLONOWSKI, J.
[1898]. A KUKORICZAMOLY. BOTYS NUBILALIS HB. (ÉLETMÓDJA ÉS IRTÁSA.) [INDIAN CORN MOTH. LIFE HISTORY AND EXTIRPATION.] 15 p., illus. [Budapest.]

(5) THOMPSON, W. R., and PARKER, H. L.
1928. THE EUROPEAN CORN BORER AND ITS CONTROLLING FACTORS IN EUROPE. U. S. Dept. Agr. Tech. Bul. 59, 63 p., illus.

(6) WORTHLEY, L. H., and CAFFREY, D. J.
1927. SCOUTING, QUARANTINE AND CONTROL FOR THE EUROPEAN CORN BORER, 1917–1926. U. S. Dept. Agr. Tech. Bul. 53, 143 p., illus.

(7) ZWÖLFER, W.
1927. BERICHT ÜBER DIE UNTERSUCHUNGEN ZUR BIOLOGIE UND BEKÄMPFUNG DES MAISZÜNSLERS (PYRAUSTA NUBILALIS HÜBN.) IN SÜDDEUTSCHLAND 1926. Arb. Biol. Reichsanst. Land u. Forstw. 15: [355]–400, illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

October 26, 1929

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration.	C. L. MARLATT, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food, Drug, and Insecticide Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Bureau of Entomology	C. L. MARLATT, *Chief.*
Division of Cereal and Forage Insects	W. H. LARRIMER, *Principal Entomologist, in Charge.*

U. S. GOVERNMENT PRINTING OFFICE : 1929

For sale by the Superintendent of Documents, Washington, D. C. - - - Price 20 cents